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Jet Fighters

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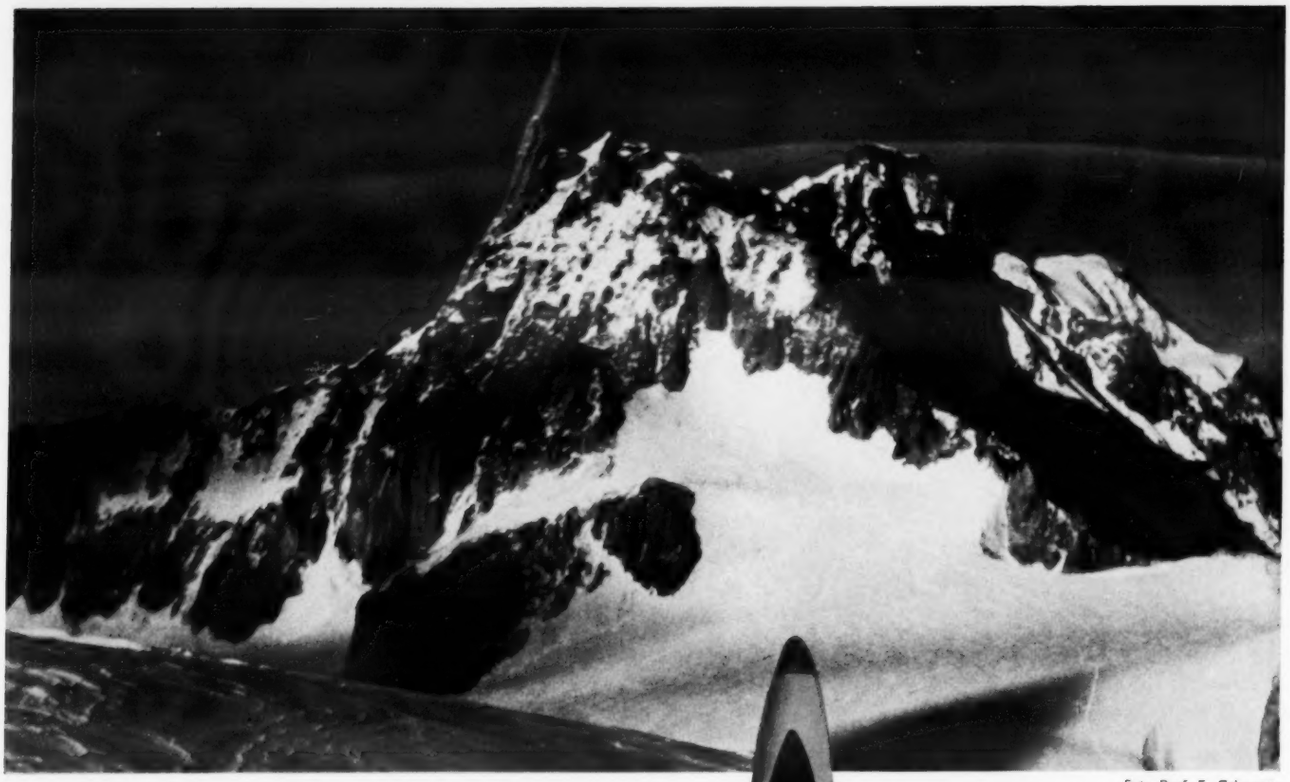

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A Grumman F9F-2 "Panther" jet fighter of the U.S. Navy doing a roll in the skies of Long Island, New York.

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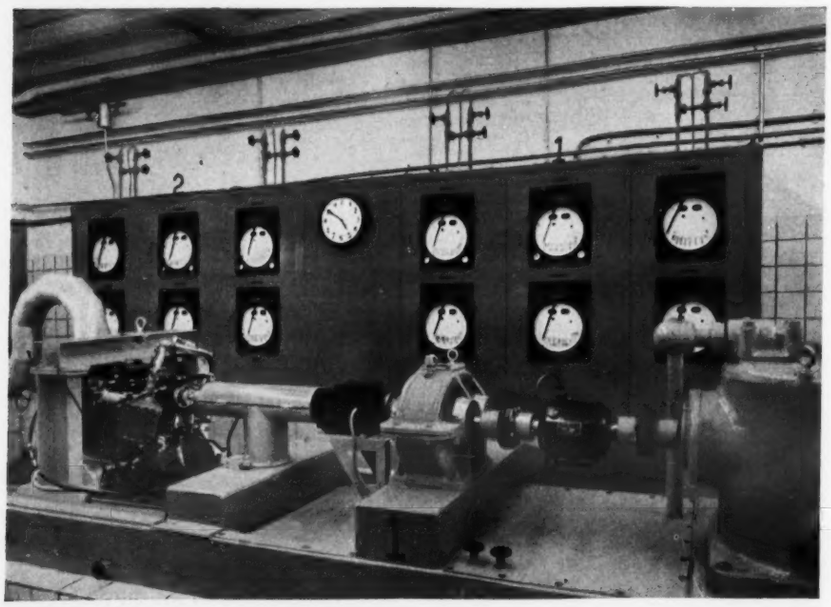

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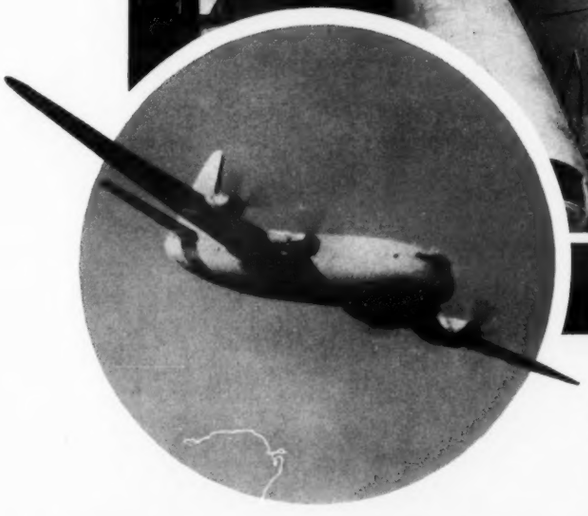

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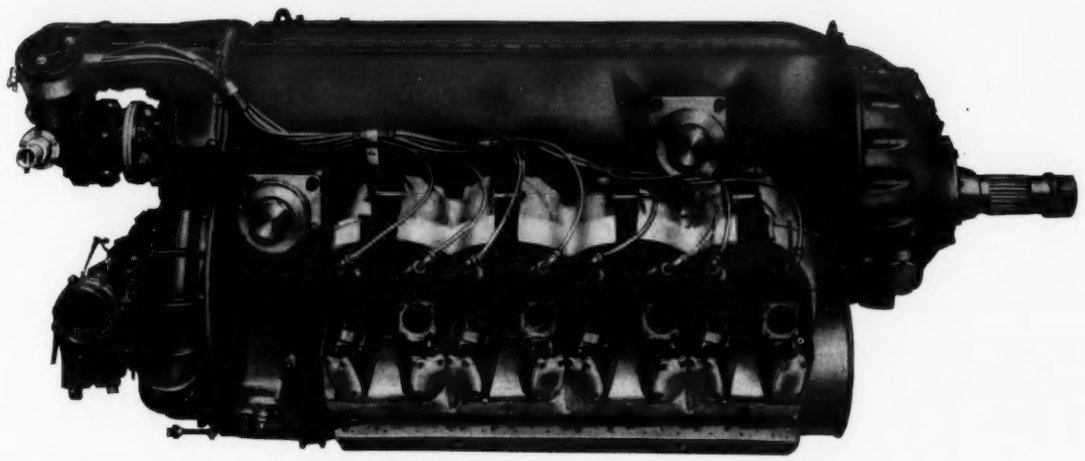

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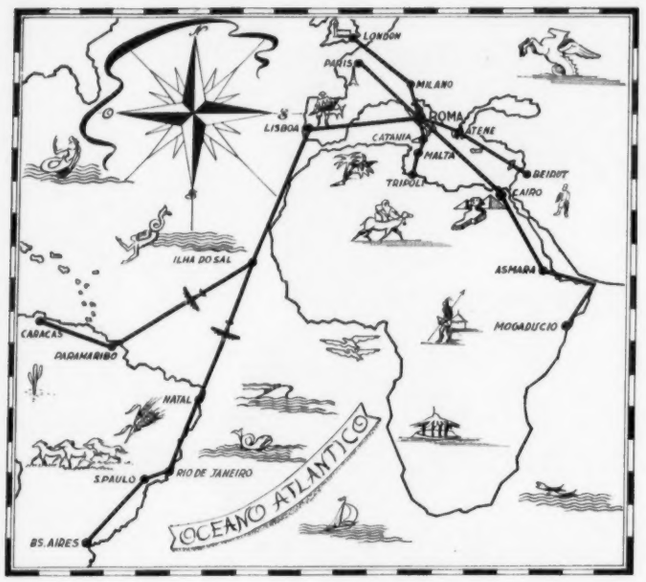

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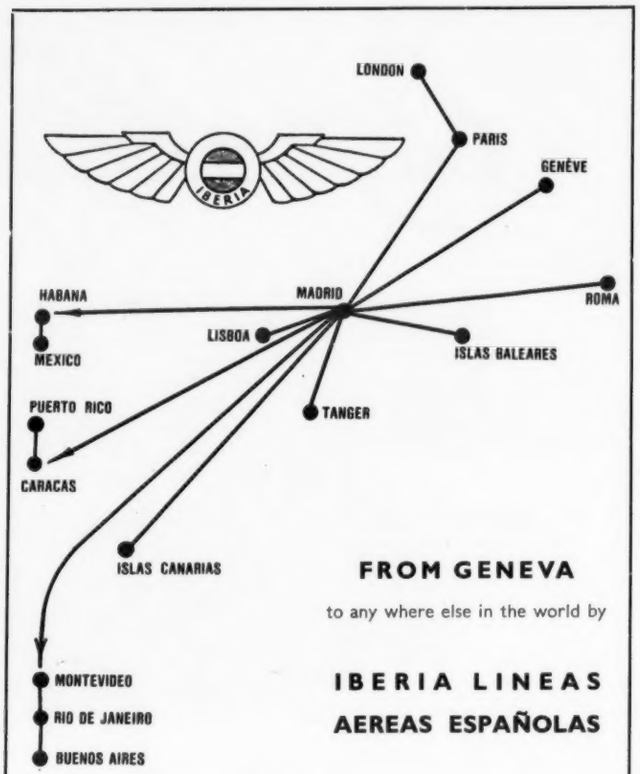

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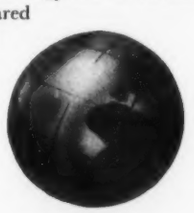

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Jet Fighters

How Good Are Today's Jet Fighters?

Gaps in the Air Defence System

BY LIEUTENANT-COLONEL PIERRE M. GALLOIS, PARIS

It was at the very moment when the majority of the military powers of the world decided on a predominantly defensive policy that the fighter formations of their air forces were found to be the least capable of stopping an air offensive. Today it has become apparent that no defensive air organization at present in existence is capable of fulfilling its part in the defeat of modern bombing raids. Whereas in 1940 the Vickers-Supermarine "Spitfires" and Hawker "Hurricanes" with their six or eight machine guns were a match for the Heinkel He 111s, Dornier Do 17s and Junkers Ju 87 "Stukas" assaulting Great Britain; whereas five years later the Third Reich was beginning to assemble the means of denying its air space to the Allies' day and even night bomber forces, today there is no piloted fighter aircraft capable of intercepting, with anything like successful results, modern bombers such as the Boeing B-47 "Stratojet" in the West or the new Tupolev Tu-10 or Ilyushin Il-16 in the East.

This, at any rate temporary, relative invulnerability of the modern bomber has extensive repercussions. Aerial supremacy, that is, the "power to use the air space for offensive, defensive and supply operations, at the same time preventing the enemy from doing likewise," will no longer be attained by inflicting heavy losses in flight and on the ground. Since they can pierce the defence network the new offensive formations no longer depend for success on a prior neutralisation of the enemy fighter forces. By the very fact that they exist, they possess one of the forms of aerial supremacy, namely the power to conduct offensive operations in the enemy's skies without, however, being able to deny the enemy the same advantage, on condition naturally that he possesses a similar class of flying equipment. Thus the classic form of air battle first between fighters and then between fighters and bombers will be replaced by attacks on enemy ground forces by these jet bomber formations which seem to mock the defence. But since speed has to be paid for, notably in range, this argument is valid only within a relatively short distance of the front, *i.e.* within about 250 to 300 miles on either side of the lines.

Thus it is not only the very small difference between the speeds of present-day fighters and bombers which suggests that the problem of the fighter arm be re-examined. Although it is regularly crossed by experimental aircraft, the "sonic barrier" is still a very real obstacle to combat aircraft. And, whether they are designing fighters or bombers, technicians are hampered by the limits it imposes and particularly by those encountered in the supersonic range. Since available propulsion units are more suitable for fighters, the latter will continue to surpass the bombers in speed, but by an amount which is insufficient to restore to the former the decisive advantages they at one time enjoyed over the latter.

If the "sonic wall" groups both pursuers and pursued before it, the "barrier of distance" has been considerably set back, thus sweeping away the old concept of the fighter escort. As for the very heavy bomber which sacrifices speed to range, if it is delivered without protection to the mercy of the defences it can find safety by flying at very high altitude where it partially escapes detection and can approach in a region of space in which the majority of fighters in service in the air forces of today have difficulty in operating. By its size, finally, it forms a detection and gun platform superior to that of its adversary and consequently it possesses in theory the ability to strike more tellingly than the latter. The atom bomber brings new tasks for the fighter, namely to intercept it successfully before its target is reached, the destructive power of the atom bomb being so great that it is infinitely more valuable to prevent the attack than to destroy the bomber.

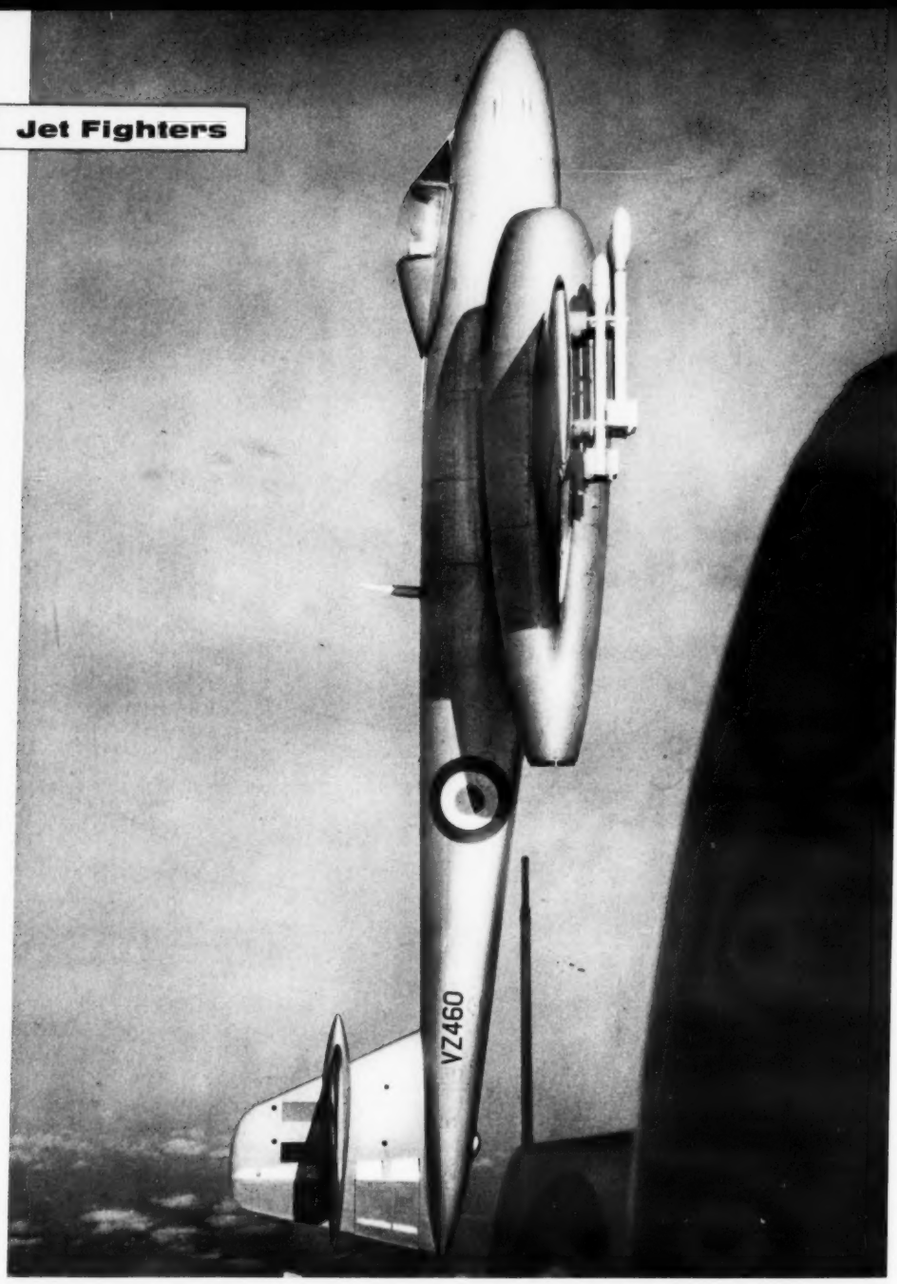
Out-classed by the light and medium jet bomber, unsuitable to escort heavy and super-heavy bombers, perhaps not even capable of defending key points against isolated raids by atom "super-bombers," the classic jet fighter may also be powerless against tactical aircraft. If the ground attack aircraft is itself a converted fighter, it is probable that the difference in speed between the two will be of the same order as that between the jet bomber and the fighter. If the ground attack aircraft is fitted with a propeller turbine, like the Douglas XA2D-1 "Skyshark," its range at low altitude will be in its favour, since although the jet fighter is faster it cannot take full advantage of this superior speed for long.

Finally, and above all, the conventional jet fighter of today has two natural enemies, night and bad weather. Jet fighters are particularly limited in ceiling, margin of speed over medium bombers, range and above all all-weather operation. They can only operate in clear weather, within a region too small to enclose all the normal objectives.

Technical problems...

The technical problem set the engineers was not simple. Above a Mach number of 0.7 the increasing drag of the wings requires greater and greater engine powers. Even to progress from the 375 m.p.h. of the "Spitfire Mk. 5" to the 590 m.p.h. of the Gloster "Meteor IV," engine power has had to be increased from 1300 h.p. to the equivalent of about 10,000 h.p. To cross the threshold of sound[1] considerable ac-

[1] The aircraft considered here are those capable of military use, and not purely experimental machines such as the Bell X-1 or the Douglas D-558 "Skyrocket."



The twin-engined Gloster "Meteor" is the standard medium-weight fighter of the British Royal Air Force. Picture shows a "Mk. 8" in a loop. The "Meteor" is a typical "general purpose fighter" as defined by the author of this article.

celeration is required, less for a fighter than for a bomber, but still enough to necessitate a combination of special wing design with engines of very large dimensions. At high altitude, the critical region is still greater and necessitates a very high thrust. Calculations show that the transonic jet aircraft, of conventional design, *i.e.* with a swept wing of between 30 and 40 degrees, would have to be powered by a turbine producing some 17,500 to 20,000 lbs. of thrust above 39,000 ft. Already experiments are being carried out to give machines a power on the ground seven or eight times greater than this. In fifty years the Wright brothers' 12 h.p. engine has developed into the 20,000 h.p. of certain ram jets. But the power curve of engines will have to rise even more steeply than it has done, now that aircraft have poked their noses into the sonic zone.

The inadequacy of the new propulsion units available has undoubtedly contributed towards the stabilisation of speeds below the speed of sound. The engineers have fined down the outlines and lightened the structure so as to get good performances. It is probable that the combination of the airframes recently designed in the USA with the most powerful jets produced in the United States or Britain (Armstrong Siddeley "Sapphire" for example) will enable the performance of these aircraft, suitably reinforced, to be considerably increased.

Finally, the greater performance becomes, the more important become accessories and equipment.

. . . and intellectual ones

But the intellectual factor must not be passed over in silence. It is incontestable that the introduction of jet propulsion, combined it is true with a reduction in the credits granted for military aviation, has given a new lease of life to the impossible idea of the multi-purpose fighter. Befogged by the new possibilities of the instrument given to them, both operators and technicians have seen only the advantages without allowing for the limitations. Rendered less exacting by the cessation of hostilities and lacking facilities for experimentation under service conditions, they have discarded the principle of specialisation and placed all their faith in the fighter, investing it in their own minds with the supreme ability to cater for all military needs.

Reviewing the composition of the air defence forces lined up by the belligerents in 1945, an eminent technician enumerated no less than fourteen different categories of aircraft, and even he did not make any reference to some of the combinations of categories. The appearance of the jet engine put a sudden stop to this effort towards specialisation and each country has since contented itself with one or two types which it regards as capable of doing everything.

The United States, being geographically so isolated, was little concerned with the problems of short range defence and retained for a long time the Lockheed "Shooting Star" in very much the same form as Lockheed had designed it in 1943. With its low rate of climb and its range of nearly 1250 miles at economic output, the "Shooting Star" could pass for an all-purpose fighter. Its operational height and its range were commensurate with Federal territory and its speed made of it a formidable weapon for the interception of conventional bombers cruising at less than 375 m.p.h. with a ceiling of approximately 32,500 ft. And the F-84 alone, or its derivatives, was to replace the North American F-51 "Mustang" and Lockheed F-38 "Lightning" escort fighters, the Republic F-47 "Thunderbolt" fighter-bombers, and even the Northrop F-61 "Black Widow" night fighter. However, it is not as easy to adapt for use in support of the ground troops as the "Thunderbolt" or the "Mustang." Exercises between strategic air forces and defensive units have demonstrated the advantage of the former over the latter, and a return has had to be made to the idea of night interception fighters and the F-80 "Shooting Star" developed into the Lockheed F-94, the thrust of the jets increased by afterburning and above all serious consideration given to the provision of specialised material for

the multiplicity of tasks covered by the defence units. It was not until the beginning of 1949, however, that the first prototype for interception at high altitudes (Republic XF-91) was flown and heavier machines, known as "penetration fighters," such as the Lockheed XF-90 and the McDonnell F-88 "Voodoo" were tried out. Thus, in spite of the considerable resources it already possessed, the USAF persisted in seeking a compromise aircraft rather than working towards narrowly specialised fighter equipment.

Great Britain also seems to have followed a similar policy. Her geographical position, however, necessitated from the first that the accent be placed on interception at height and at short distances from national territory. The de Havilland "Vampire" and the Gloster "Meteor" are the result of the best possible compromise between the armament and range required on the one hand and the rate of climb and speeds on the other. But the concentration of technical and financial effort on these two types and on their progressive improvement left large gaps in British air preparedness. It is only since last year that the "night" versions of the "Vampire" and "Meteor" have been flying.

Not much is known about the direction followed by defensive aviation in the Soviet Union. But the fact that the rocket-engined Messerschmitt Me 163 of the end of World War II has been taken over by Soviet engineers (Yak-21) suggests that short-range air defence has not been neglected and that at least two of the three fundamental categories of fighters—the light fighter (Yak-21) and the medium fighter (Mig-15 and La-17)—have been followed up, although the heavy escort or strategic intervention fighter do not appear to figure among the prototypes behind the Iron Curtain.

As for France, under-estimating the relative size of her territory and the very brief warning which would be available to her defence organization, she turned to the heavy fighter, heavily armed, with a relatively long range, but paying for these advantages with a low rate of climb. It was not until later that she tried to provide herself with interception material comparable with that of the Royal Air Force Fighter Command, accepting a compromise which gave a greater rate of climb and improved manoeuvrability at altitude. The composition of her forces did not demand very long range material, and she shared with Great Britain the same day and night interception programme. Although the first part of this requirement was fulfilled, the second was not.

It is vain and even dangerous to accentuate ones advantages in a given field of action if the other side has to be ignored, since the enemy will always strike where he is strongest. The best of day fighters is not good enough if the enemy's night bomber arm is powerful. An attack at very high altitude or close to the ground may be effective if the defence has specialised in interception at medium and high altitudes.

The F-84F, latest addition to the Republic F-84 "Thunderjet" family, is about to go into large-scale production. The USAF proposes to use the type as a ground-support fighter.

The Mig-15 is the Russian equivalent of a general purpose fighter. Its low wing loading gives it great manoeuvrability.

The forms which hostilities can take on are so numerous and so diverse that any of a great variety of weapons can be decisive—particularly those to which the enemy has given little attention.

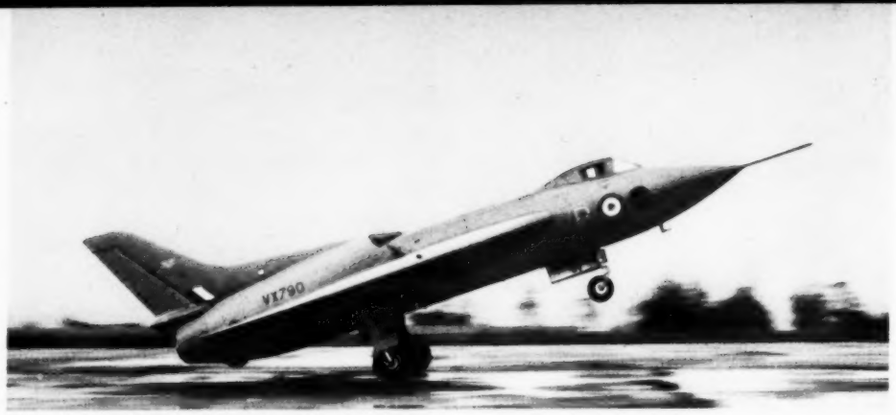
It is for this reason that a re-examination of the principles on which existing air defence organizations were founded will be admitted to be in order.

Phase I

1. *Subsonic range* (at least until 1955)

Now should such a question be approached? The task to be accomplished, varying with the weather, decides the first step. Once the different missions to be filled and the most suitable material for them have been defined, operational factors will doubtless tend to favour a compromise between narrow specialisation of types and material which can be used for several different purposes. Then, passing from the general problem of air defence to the concrete case of a given nation, only that material which meets the imperative needs of defence will be retained. A fresh compromise will then become necessary between the theories thus retained and the technical, financial, human and even psychological resources which govern the materialisation of any such plans.

Speed, ceiling, range of the enemy in the air or, more generally, of the enemy aircraft to be destroyed or the friendly aircraft to be protected delimit the field of action of fighter material. Operational requirements, potentialities of auxiliary forces on the ground, geographical considerations such as distance from or proximity to large built-up areas requiring defence represent so many technical, political or natural factors which are sufficiently important to require that the aircraft acquired should be not only specialised according to category of mission, but also properly adapted to a given theatre of war.



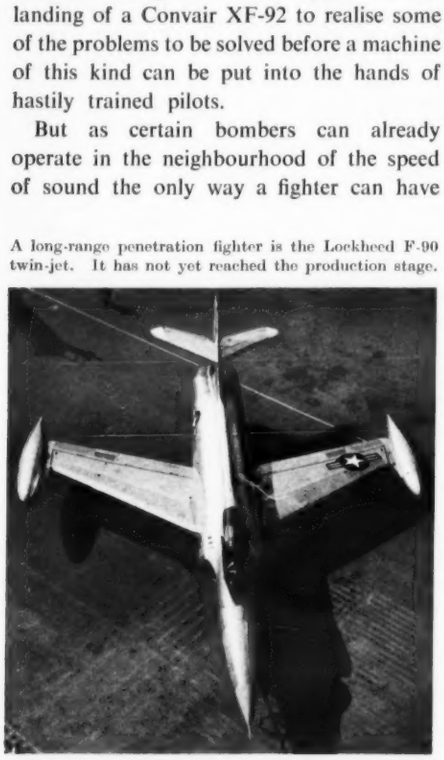
The Delta-wing fighter might bridge the gap between today's subsonic and tomorrow's supersonic fighters. This picture of the landing of the Avro 707B experimental aircraft graphically illustrates the fact that this type of aircraft can hardly be entrusted to fledgling pilots.

2. *Subsonic Aircraft*

First the question of speed. Of the known military prototypes which are sufficiently advanced for quantity orders to be placed, none are in the supersonic class. The design of the most recent machines, the range of engines available and the numerous problems, not yet solved, connected with operational supersonic flight seem to indicate that it will be at least the middle of the present decade before pilots of combat units begin to fly as a normal thing beyond the speed of sound. For conventional airframes, with swept wings, the power required to pass rapidly through the critical zone is prohibitive, and fuel consumption would be too high to give the fighter the range which is *essential* in a combat aircraft. If jet propulsion is regarded as the only answer, there remains the delta wing as a possible solution. It is probable that Convair's experiments with the XF-92 in the USA, and Boulton & Paul's and Avro's with their respective prototypes in Britain, are aimed at the development of a combat aircraft to bridge the gap between today's subsonic fighter and the supersonic fighter of tomorrow. Up to a speed one and a half times that of sound the combination of triangular wing and jet propulsion is without doubt the best. But this time the obstacle to be surmounted concerns the airframe rather than the engine. And it is enough to look at a picture of the landing of a Convair XF-92 to realise some of the problems to be solved before a machine of this kind can be put into the hands of hastily trained pilots.

But as certain bombers can already operate in the neighbourhood of the speed of sound the only way a fighter can have sufficient advantage over them is to be frankly supersonic, or to have at least the benefit of a few extra "tenths of Mach."

A long-range penetration fighter is the Lockheed F-90 twin-jet. It has not yet reached the production stage.



However, the Convair XF-92, the first of the delta wing aircraft, has not yet been ordered in quantity. It is therefore still reasonable to estimate that it will be at least the middle of the decade before real transonic or supersonic combat aircraft are in practical use. The present preoccupation with rearmament, it is true, will accelerate research, but it will also freeze technical development where production is concerned. The machines now on order will be supplied to the units in eighteen months or two years and will remain in service at least two or three years afterwards.

3. *The sky has limits*

As regards altitude, it will be remembered that the Convair B-36 super-bomber is said to operate at 52,000 ft. and that the "Ghost-Vampire," holder of the altitude-record for powered aircraft, has climbed to over 59,000 ft. Unfortunately, at this altitude, the pilot's margin of speed between the critical Mach number and the stalling speed was less than 37 m.p.h. The present-day fighter would seem to be reduced to flying, under normal conditions, in the lower stratosphere, *i.e.* below 48,000 ft.

Range is the most severe of the limitations from which the jet aircraft suffers. It is in fact so severe that it seems to have eliminated for the time being the escort fighter and has imposed on the strategic fighter a weight greater than that of the medium bomber of only ten years ago.

Moreover, the limitations imposed by reduced range, particularly at low altitudes have necessitated a more complicated ground organization and, in the aircraft itself, navigation equipment of a sufficiently high standard to eliminate the necessity for circuits before landing.

It is these technical difficulties, which will be valid at least until 1955, that set the limits within which engineers and users must design and operate the material provided for the various missions allotted the fighter arm. Barely transonic maximum speed, operational ceiling less than 48,000 ft. abolition of fighter escorts and interception at low altitudes, such would appear to be the limitations imposed by technical handicaps on engineer and strategist.

4. *The three minimum missions*

What are these missions? The destruction in flight of a subsonic adversary in a region of space whose dimensions are constituted by range and ceiling, both increased to their maximum, presupposes the reconciliation of technical and operational requirements which are irreconciliable in one and the same machine within the framework of the same employment theory. Therefore it is at least essential to distinguish between the following missions, each of which is performed by an aircraft of a special class or by the combined use of two or more different classes of machine:—*a*) air defence of the interior; *b*) tactical operations in front of, above and behind the lines; *c*) long-range or strategic operations.

a) *Air defence of the interior*

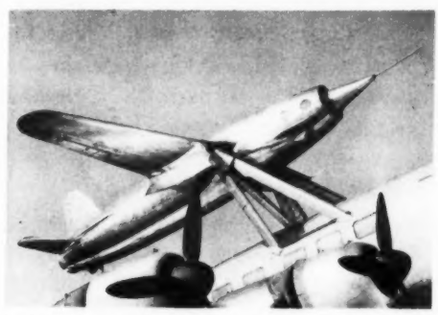
Here the essential requirements are a very high rate of climb (of the order of 19,500 ft./min. near the ground) and excellent manoeuvrability at altitude. Speed in horizontal flight should of course be as near as possible to the speed of sound.

In the present state of technical development such performance cannot be obtained without sacrificing other requirements. Since range would be of secondary importance, the aircraft designed to defend built-up areas could be entirely dependent on its ground organization. The designer could save weight by abolishing the undercarriage and economising on detection and navigation equipment, which could be reduced to a fire control system and a homing device for return to base. The ground station, on other hand, besides having launching equip-

ment, would guide the aircraft to the target and back to the ground once its mission was completed.

b) *Tactical operations*

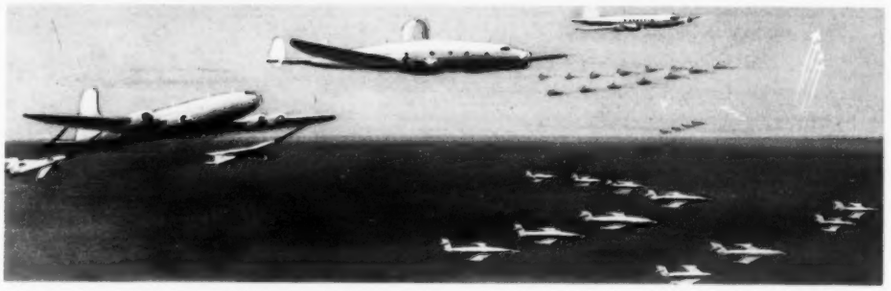
The material suitable for this mission appears to be that with which the majority of fighter units are now or are about to be equipped. It is the result of a compromise between the contradictory demands of very good rate of climb, high speed, good range, powerful armament and the ability to use average size airfields. Here the concessions made concern flight at very high altitudes—missions carried out by the light interceptor, already described above—and intervention near the ground which, if it were to be protracted, would require an impossibly high fuel reserve. Flying at Mach 0.9 at least, powered by a jet engine of 5,500 to 6,600 lbs. thrust, and weighing 13,000 to 15,500 lbs., it would have an endurance of 2 hours. As it would operate primarily in the operational zone of the ground radar, it could leave behind part of the detection equipment essential in the fighter with a longer range. It is of course this aircraft which in the zone of the interior, would stop up the "gap" between the ceiling of the A/A units defending particular nerve centres and the lower interception limit of the high altitude light fighters.



Design of the Leduc 010 experimental ram-jet aircraft was started "underground" during the German occupation of France. Leduc is working on ram-jet aircraft of even more advanced design.

c) *Strategic fighter*

This differs from both the foregoing in the extent of its navigation and detection equipment and, of course, in its endurance. A long-range two-seater (endurance approximately 4 hours without external tanks), its weight is relatively high (30,000 to 40,000 lbs.), it would have auxiliary boosters which, added to afterburners, would enable it to evade an enemy interceptor with greater speed but tied to its base because of its low endurance. Its two axial compressor jet engines would help, thanks to their good specific consumption, to reduce the disadvantages inherent in a method of propulsion still so extravagant in fuel.



The creation of long-range air defence task forces has been suggested. Such a force would consist of a "flying headquarters" (top right), a "radar search aircraft" (top centre), several tankers for mid-air refuelling of fighters, and substantial formations of high-speed fighters. These task forces would patrol the sky to intercept high-flying enemy bomber formations. The interception and destruction of enemy bombers—particularly aircraft carrying A-Bombs—long before they reach their targets has become imperative.

These three categories of aircraft, in particular the first and the last, should have one characteristic in common, namely the ability to operate whatever the atmospheric conditions. They would be armed with 30 mm cannon during the first period, rockets during the second and eventually no doubt, depending on the nature of their aerial targets, with air-air missiles.

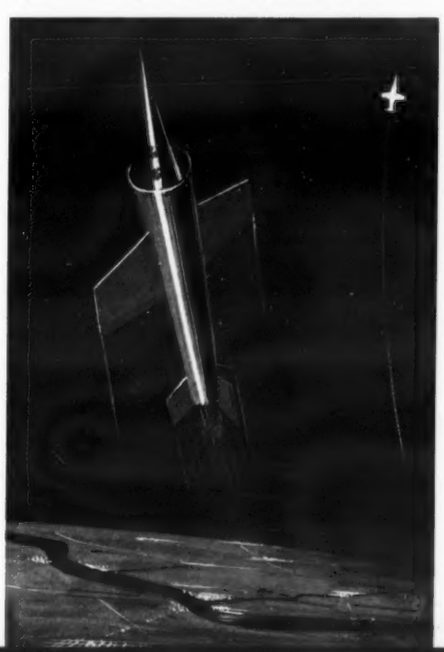
If the performance of the machines existing today is compared with that of the aircraft regarded as indispensable to the minimum defensive organization, it will be admitted that only the very high altitude interceptor has not yet been sufficiently developed. However, the transformation of existing medium and long range aircraft into "all-weather" machines is an urgent necessity.

Phase II

The ram-jet (after 1955)

During the second phase already envisaged, that is from 1955 onwards, the ram-jet should, if all goes well, enable the air arm to make an even more spectacular advance than has resulted from the general introduction of turbo-propulsion. The field of activity of defensive air forces will then be suddenly enlarged, speed exceeding twice that of sound, ceiling reaching 97,000 ft., with a satisfactory range from the operational point of view into the bargain. At the same time it would be possible to glimpse solutions to the problems of manoeuvrability at altitude and stability at low speeds. Finally the financial burden due to the complexity and the growing weight of present-day aircraft would be reduced in view of the relative simplicity of constructing and maintaining the new power unit.

The future ram-jet fighter for high supersonic speeds. Its mission would be purely that of a short-range interceptor with an operational ceiling of 100,000 ft.



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Meanwhile, the combination of a number of technical developments should make it possible to increase the efficiency of the present-day defensive air instrument. It is a fact that, however precarious it may have been, peace has not been over-exacting as regards air armaments. If the progress made during the past five years is compared with the defence techniques tried out by the Germans during the last months of the war, it will be admitted that conventionalism has triumphed over imagination. It is only recently that large-scale experiments have been carried out into the refuelling of fighters in flight and that a new method of employment has been sketched out which should reduce the disadvantage of the jet's heavy fuel consumption. And it is only recently that the provision of a fighter capable of operating in all weathers has become one of the first preoccupations of air staffs and designers. True, even though the aircraft involved fall into the light category, a fighter arm is a costly affair. However, shortage of funds should not and may not become an invitation to resignation or conventionalism, nor an excuse for lazy thinking.

Jet Fighters

Riding in a "Meteor"

An Amateur Pilot's Impressions

BY BÖFFIN *, LONDON

I never thought it would be possible, but at last I can do it! I can lean on the bar at the Flying Club, downing my pint after half an hour's exhilarating stooging in an "Auster" lightplane, and say: "There we were, upside down, at zero feet and climbing hard with nothing on the clock..." The old RAF chorus that greets anyone who starts to "shoot a line" in the mess about his adventures is inevitable—only the "line" is fact in this case. Anyone who is offered a flight in a Gloster "Meteor" twin-engined jet fighter (trainer version), and who shows he is really keen, will be treated to an exhibition of its amazing rate of climb—*upside-down*. Depending upon the pilot, this may be shown to you at 10,000 feet or at take-off, when the aeroplane is rolled on to its back at a terrifyingly low speed and then climbed at a steeper and steeper angle. As an aerobatic manoeuvre, the "Meteor" can be turned on its back and then climbed up and over, in an upward inverted half loop, until it is right way up again.

But to get on with my story.

As a private pilot of some fifteen years' standing the opportunity of flying in a Gloster "Meteor" Trainer, the Mark 7, came as a very great thrill indeed. I have flown many types up to three or four hundred horsepower, but any high-powered experience was limited to a couple of ecstatic occasions when I was given dual on the Fairey "Firefly" naval strike aircraft and Supermarine "Spitfire" fighter trainer. Therefore the following notes, written soon after landing, can be taken as being representative of an amateur pilot's reactions to jet flying.

In the rear seat of the "Meteor 7" the forward view is obstructed to some extent by the pilot's head and the sturdy framing of the long hood, but the general view is excellent. Normally the pupil is in front, but officially I was a passenger only, so I

"There we were, upside down, at zero feet and climbing hard with nothing of the clock..."

was in the back with slightly reduced instruments, *i.e.*, without operational items and fuel pressure and contents gauges. As an amateur, I always feel a little self-conscious in a parachute and, when bundled in my seat with straps and release boxes for 'chute and Q-type safety harness, I seemed about as encumbered as Tweedledum girt for battle—mercifully, as we were flying inland, I was spared the added bulk of a Mae West. However, I soon began to get acclimatised and, by the time the engines had been started, felt at home and had begun to know where to look for the dial I wanted to consult.

The Rolls-Royce "Derwent" engine is turned by an electric starter, using ground batteries, and by the time 1,000–1,500 r.p.m. are reached the engine starts to pick up on its own. It is then opened up to 10,000 r.p.m. with some care, as it can easily be put out at this initial stage by careless use of the slide throttle. The second engine is then started. When the engines are running there is a deep hum and a slight tremor; none of the usual noise and vibration. Apart from the opening-up stage, no warming-up is necessary and, with a little more power to start the "Meteor" rolling, it taxies along at 9,000 r.p.m. and is steered on the brakes.

If you are a keen type, the pilot of a "Meteor 7" will show you an inverted climb after take-off—that is what this pilot of a "Meteor 4" is doing. This photo was taken from the *end of the runway*...

Lined up on the runway the engines are given about half throttle; then the brakes are released and the "Meteor" surges forward as the engines are opened up to 14,000 r.p.m. At about 80 knots I.A.S. the nosewheel can be lifted off the ground, then at 120 knots the stick is eased slightly back and the Meteor lifts off the runway, to be held down until the safety speed of 160 knots is reached, during which time the wheels must be quickly braked and the undercarriage raised. When the speed has built up to 260 knots backward pressure on the stick sends the machine up like a rocket—initially about 7,000 ft./min.—with a noticeable *g* effect. Reducing climbing speed by 10 knots I.A.S. for each 5,000 ft. and closing the throttles to keep the r.p.m. down to 14,000 we soon reached 28,000 ft.

During the climb a glance at the instruments made my eyes pop! The needle of the rate-of-climb indicator was showing a *descent*, because it had gone round past its maximum climb reading, while the triple-hands of the Kolsman altimeter were spinning round as if they were running away.

During the take-off I only "followed" the pilot with my hands and feet on the controls, but I was allowed to take over on the climb. I was then able to try the Meteor's controls in straight flight and gentle turns as we left far below the lovely tinted patchwork of Kent that could be seen through gaps in the ragged, vicious masses of cu-nim that made the skyscape of a typical English

* Not the character in Charles Dickens' Mutual Friend, but the RAF World War II expression for the "back-room boy," the technical and scientific expert.

July day last summer. Above the white caps and in the dazzling blue, the Meteor's wings projecting beyond the fat nacelles seemed incredibly tiny. Levelling out I tried the controls in turns, vertical turns, figures-of-eight and slow rolls. The control column is the customary jointed "stick" with a spade grip, common to all British fighters, while the rudder pedals are like roller skates that run in rails—so that both feel a little strange at first to an amateur. The rudder is curiously solid, without being heavy, the elevators light enough to be easily controlled but heavy enough to prevent inadvertent misuse and excessive *g*. The ailerons are light and very effective, giving a very rapid roll. Although all controls are light, they give the feeling that one is moving mighty forces through them—in this they resemble the "Firefly" rather than the "Spitfire."

Naturally, one of the most interesting things to be seen was the compressibility, or Mach effect. In level flight the pilot opened up to full throttle and the speed built up gradually as the needle of the Machmeter moved into the marked segment on the dial—.72 to .83. First the stick began to kick and buffeting caused the airframe to shudder slightly and then the snaking started. The nose just weaves about over a range of a couple of degrees, entirely out of the pilot's control, but not increasing in any way to a dangerous extent, although as the speed rises the buffeting gets more violent at about M = .825 or .83 (565 m.p.h. at 28,000 ft.). At this point the pilot opened the air brakes and I was thrown forward on my straps at the sudden deceleration as we rapidly lost speed down to 300 knots I.A.S. These brakes are flaps in the wing centre section, which are opened hydraulically and allow a descent at 10,000 ft.min. with an air speed of less than 300 m.p.h. They are an essential flying control on a jet aeroplane, where there is no airscrew drag when the throttle is closed, and therefore the lever is mounted just below the throttles, so that they can be used together.

If we had continued to accelerate, the "Meteor" would have then shown the usual nosedown tendency, followed by a rolling instability with, finally, a wing dropping sharply as the airflow broke away in a compressibility stall. In these compressibility phenomena the "Meteor" is much more docile than most of the jet fighters in service today, some of which have the very sharp nosedown change of trim that cost many lives before the use of air brakes was developed.

Gloster Meteor T Mk. 7

Dimensions

Span	37 ft. 2 in. (11.3 m)
Length	43 ft. 6 in. (13.25 m)
Height	13 ft. 0 in. (3.96 m)
Wing area	250 sq.ft. (23.2 sq.m)

Weights

Tare weight	10,290 lbs. (4,660 kg)
Removable equipment	118 lbs. (54 kg)
Crew, parachutes, dinghies, etc.	447 lbs. (203 kg)
Fuel and oil	2,683 lbs. (1,217 kg)
Ballast	462 lbs. (210 kg)
Gross weight. v.	14,000 lbs. (6,344 kg)

Engines: Two Rolls-Royce "Derwents" of 3,500 lbs. static thrust each.

Performance (at take-off weight)

Max. speed, sea level to

10,000 ft.	585 m.p.h.	(940 km.p.h.)
20,000 ft.	570 m.p.h.	(915 km.p.h.)
30,000 ft.	520 m.p.h.	(832 km.p.h.)
40,000 ft.	490 m.p.h.	(790 km.p.h.)

Rate of climb, sea level

	8,000 ft./min.	(46.5 m/sec.)
10,000 ft.	6,700 ft./min.	(34 m/sec.)
25,000 ft.	5,200 ft./min.	(25.5 m/sec.)
30,000 ft.	3,650 ft./min.	(18.5 m/sec.)
40,000 ft.	2,050 ft./min.	(10.5 m/sec.)

Range at 30,000 ft. (9,150 m.) internal fuel only (325 Imp. gals = 1,480 litres)
470 miles (752 km.)

Take-off to 50 ft. (15.25 m.) 785 yds. (720 m.)

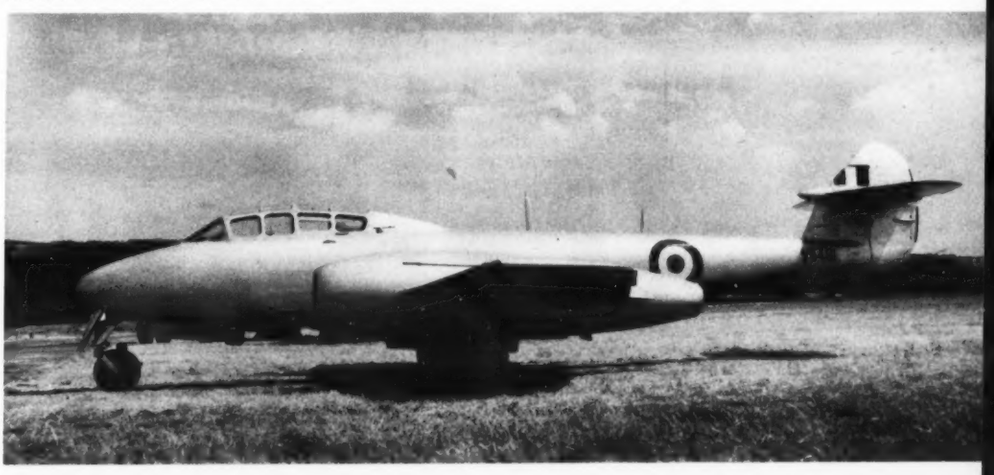
Landing from 50 ft. (15.25 m.) 935 yds. (850 m.)

A few slow rolls (with some not altogether perfect follow-ups by the "pupil") were a convincing demonstration of the "Meteor's" powerful ailerons. The roll is started best at 260 knots I.A.S., but it can be done faster or slower. When asked for a roll off the top the pilot opened up to get the necessary 380–400 knots I.A.S., only to find the Machmeter needle rising too far—so that he opened the air brakes and we descended rapidly with the nose stuffed down at what seemed to be about 45 degrees. Then, opening up, we rose in a vast loop of some eight or nine thousand feet in diameter. Experiencing quite enough *g* for comfort, the climb seemed slow and long, before, at last, the far horizon came in view through the top of the windscreen and we rolled neatly into the horizontal.

Fuel was by now beginning to get low, so the air brakes were whipped out again and we came rapidly down through a gap in the clouds, misting up severely in the process—sometimes the cockpit panels frost over and then things are really unpleasant. Then, close to the deck, and in some rough bumps very different from the smooth upper air, we swept downwind across the aerodrome at a ground speed of more than 600 m.p.h. (so strong, however, is scale effect that it seemed little different from a beat up done in a Tiger Moth!) Then, out came the air brakes and our speed dropped to an easy 400 as the pilot went into a turn and asked the control tower for permission to enter the circuit and land.

Throttling, the speed was reduced to about 200 knots I.A.S. and the undercarriage and flaps were lowered. Then the final approach was made at 140–150 knots, straight down

The author flew in this type of two-seater jet trainer, a Gloster "Meteor 7." This one was photographed at Moreton Vallance RAF Station, under the blue skies of Gloucestershire.



Coming down is the trouble, not going up. Air pressure cannot get into your ears quickly enough, and it is very uncomfortable if you do not blow your nose frequently—not an easy matter when negotiating a long, long, loop 9,000 feet in diameter. This is a "Meteor 8" single-seater fighter doing a loop with eight 95-lb. rocket projectiles under the wing.

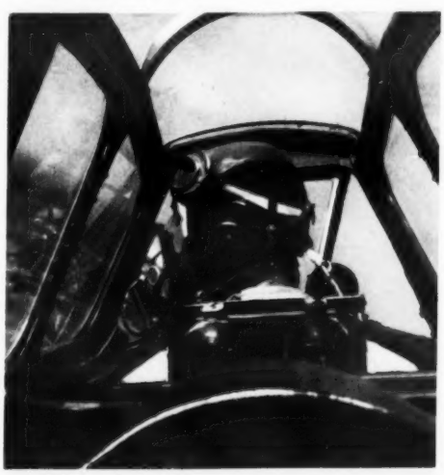
on to the runway, with some throttle and using the air brakes for approach adjustment. It is possible to make spot landings by a new technique: to come in with flap only and then open the air brakes suddenly, so stalling the aeroplane on to the ground—any carelessness, of course, may break even the Meteor's robust undercarriage. Then, daintily, right at the beginning of the runway, we touched down at 105 knots, yet as lightly as I have ever done, as the pilot cut his throttles. We ran on the main wheels, nose high in the best drag position, until the nosewheel sank gently down and the brakes could be used. It seemed warm, so the cockpit hood was thrown open as we taxied back to the dispersal point.

Impressions

This was a simple flight, no very fierce manoeuvres and no great heights (the Mk.7 has no pressure cabin), and the effect on an ordinary pilot was not great, save for some earache when coming down at about 10,000 ft./min. on the air brakes—caused by my not realising that it is still possible to blow one's nose while wearing a modern oxygen mask. Handling seems little different from normal types and, in the great tradition of the British fighters that won the Battle of Britain, well within the capabilities of anyone with reasonable piloting instincts.

Noticeable indeed was the time taken on circular manoeuvres, where large radii made even vertical turns and loops seem slow. It is impossible to see how much sky one is using when high up and one can only judge by the time taken for a full circuit—but something like 60 seconds must be needed for a full circuit or half a loop! Tighter turns than we did can be made; but only at low levels or a high-speed stall will occur through *g* loading. Again, the Machmeter has to be watched whenever speed in increased and the fighting pilot must have a tricky time thinking ahead, like a good fencer, as to what he can do next. Needless to say, a machine that has reached the snaking stage is useless as a gun platform; although it could be flown at this speed for overtaking a target and slowed rapidly to a steady speed by the air brakes. Certainly, with its moderate wing loading of 43 lb./sq.ft. the "Meteor" must be a very much handier weapon than so many other modern jet fighters with their 60 to 70 lb./sq.ft. loadings.

The general view from the rear (instructor's) cockpit is good but for the head of the man in front. It is a surprise to realise that one can really blow one's nose in this type of oxygen mask.



Another serious point to watch is fuel consumption—at full speed near sea level this can amount to some 960 gals/hr.! This is always a problem with fighters, but becomes acute with jets.

At altitude navigation presents no unusual problems and there is ample time for the identification of landmarks; but at low levels—under 500 ft.—pin-pointing is tricky. Since low level surprise attacks are part of the fighter's stock-in-trade, the recognition of a line of approach at 100 ft. and 500 m.p.h. *plus* is just one of the problems that have to be faced.

As a pilot and engineer, I knew in general terms the difficulties of manoeuvring at high speed, of the troubles of the sonic range and the effects of altitude; but reality was far more vivid than anything I had ever read or imagined. The jet pilot has fewer engine instruments than his predecessors, but the essential dials require very careful watching—jet pipe temperature—fuel contents—fuel pressure. The manoeuvres of air fighting must be combined with an alert appreciation of the readings on the A.S.I., the Machmeter, the altimeter—and on some aircraft the accelerometer. Failure to note and apply the warnings on the dials may lead to black-outs, high-speed stalls, shock stalls—any one of which can be fatal in combat. At high altitudes the pilot is literally "clamped" between his raised stalling speed and reduced critical Mach number.

My greatest surprise of all, though, was the *time* taken to perform all manoeuvres that were not in the rolling plane. At flying displays I had appreciated, quite vividly, the differences between the looping and turning radii of a "Spitfire 9" and those of even the most manoeuvrable jet fighter, but only actual experience drove home the lesson. I suppose one is misled by the fascination of speed into forgetting that the faster one goes the *slower* become all radial manoeuvres.

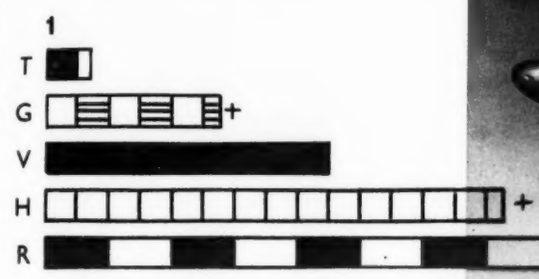
1951 Jet Fighters

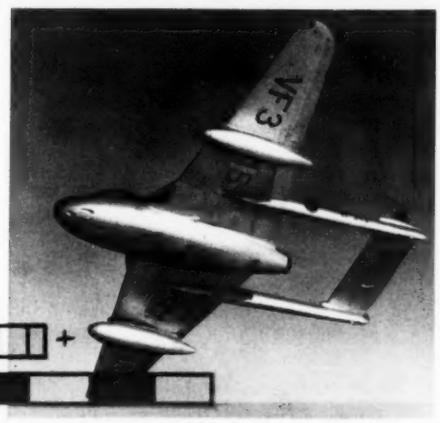
A Review

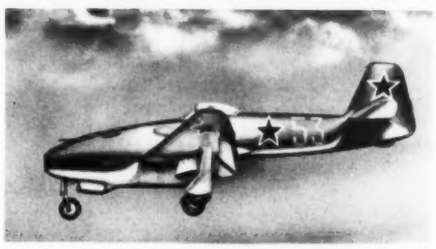
All the major military powers and most of the smaller nations are energetically expanding their fighter forces. Nevertheless, it is surprising how many new types of jet fighter aircraft have seen the light of day in the course of this process. At the end of the war four types of jet fighter were in operation; by the end of 1948 this number, including prototypes, had increased to about two dozen.[1] Today even the most stringent selection cannot reduce their number to much less than 50, of which about 33 have been or are in production. Development is going on apace. By the time these pages appear in print, new, hitherto secret types may have been announced to the public.

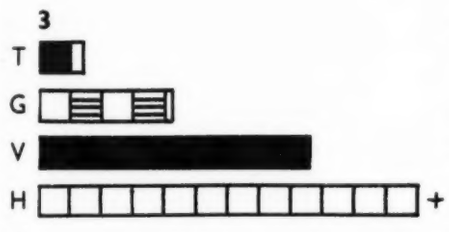
[1] Cf. "Jet Fighters 1948," *Interavia Review of World Aviation*, April, 1948, pages 198-202.

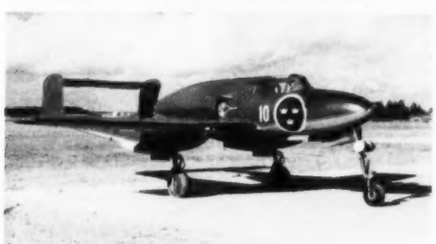
Explanation of signs:
T = Maximum static thrust (in kg)
G = Normal gross weight (in kg)
V = Maximum speed (in knots)
H = Service ceiling (in 1000 m)
R = Range (in nautical miles)
Scale of forces: 10 mm = 2000 kg
Scale of heights: 10 mm = 2000 m
Scale of speeds: 10 mm = 100 knots = 115 m.p.h.
Scale of distances:
10 mm = 100 nautical miles = 115 miles
"Plus" signs following a figure indicate a minimum value.

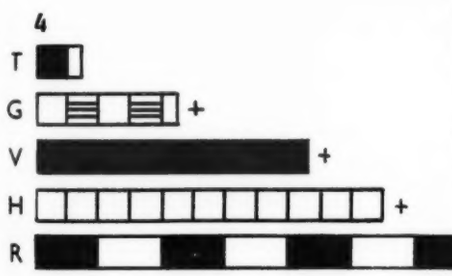


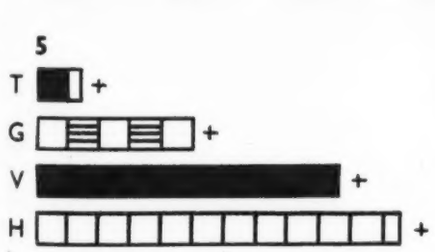


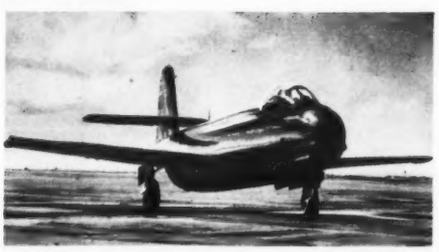












The present review lists the existing fighters in the order of the static thrust of their engines, which in most cases offers the sole criterion. It is true that this thrust can be increased substantially by means of water-methanol injection and afterburning, or by the addition of rocket units. Gross weight is known approximately only in a few of the types, and even in those models it varies within wide margins according to the tactical use and the size of the airfields for which the aircraft is intended.

Distinction has been made between single-seaters and two-seaters. Unless they are designed purely for training purposes, two-seaters are used either as night or all-weather fighters, *i.e.*, for missions in which communications, search and navigational duties would place an undue load upon the pilot.

I. Single-seaters

DE HAVILLAND D.H. 100 "VAMPIRE" (GREAT BRITAIN):

Most widely used jet fighter (developed in 1942, first flight in 1943); in squadron service in twelve countries; produced under licence in Australia, France, Italy, Sweden, Switzerland. Various versions for fighter and fighter bomber duties (F.3; *F.B.5*; F.B.6; etc.) and as a carrier-borne fighter (F.20 "Sea Vampire"). Armament: four 20-mm cannon in fuselage nose; eight 60-lb. rocket projectiles and two 500-lb. bombs under the wing. Outboard armament can be replaced with two 100-Imp. gal. auxiliary tanks.

YAKOVLEV YAK-15 (USSR):

Light jet fighter (first flight in 1946), built in large numbers in several versions (first with tail wheel landing gear, later with tricycle). Composite construction. From the tricycle type illustrated (*Yak-15B*) a two seater trainer version has been derived. Armament: one 20-mm cannon and one .5-in. machine-gun.

SVENSKA AEROPLAN J 21 R (SWEDEN):

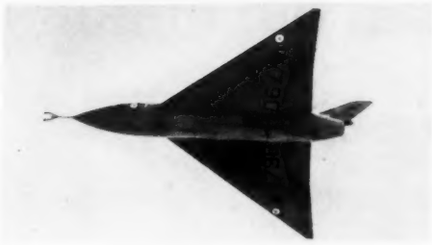
Developed from the SAAB J 21 A piston-engined pusher fighter. The J 21 R (first flight 1947) is the first Swedish jet fighter to be built in quantity. There are two versions: *J 21 RA* with a de Havilland "Goblin 2" of 3,000 lbs. static thrust; J 21 RB with an SFA-de Havilland "Goblin 3" of 3,300 lbs. static thrust. Armament: probably a 20-mm. cannon and two .5-in. machine-guns in the fuselage nose, plus two machine-guns of the same calibre in the wings; RPs under wing centre section. Auxiliary fuel tanks.

McDONNEL FH-1 "PHANTOM" (USA):

Development of this twin-engined carrier fighter dates back to 1943; production was started in 1945. A total of 60 "Phantoms" was delivered to the US Navy. Armament: four .5-in. machine-guns in the nose; eight RPs under the wing.—A drop tank can be carried under the fuselage.

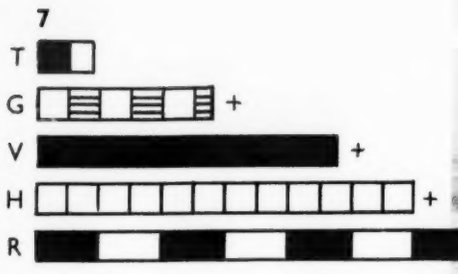
CHANCE VOUGHT F6U-1 "PIRATE" (USA):

The prototype of this carrier-borne fighter flew at the end of 1946, and the first production model was completed in 1949. Westinghouse J-34-WE-30A engine and Solar afterburner. Extensive use is made of the "Metalite" composite building material developed by Chance Vought, a "sandwich" of light metal sheets and balsa wood. Armament: six .5-in. machine-guns or four 20-mm cannon. Wing tip drop tanks.



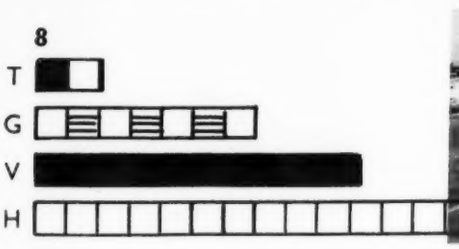
AVRO 707B (GREAT BRITAIN):

Experimental delta-wing type. A first prototype (Avro 707) started its flying trials in the autumn of 1949, but crashed after only a few flights. Tests are continuing with the second prototype (Avro 707B), which features a modified cockpit and an ejector seat.



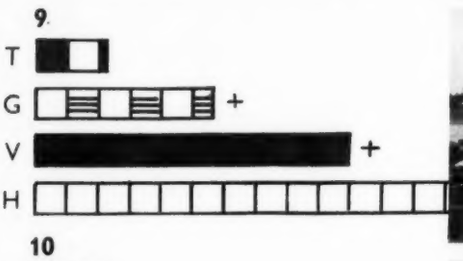
NORTH AMERICAN FJ-1 "FURY" (USA):

A batch of 30 aircraft of this type was delivered to the US Navy, but today they are used merely for training purposes. The FJ-1 was the first jet aircraft to be developed by North American Aviation and made its initial flight in November, 1946. Armament: six .5-in. machine-guns in the nose. Wing tip drop tanks.



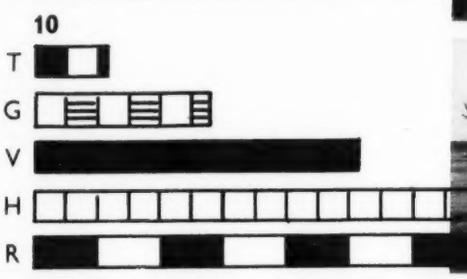
LOCKHEED F-80 "SHOOTING STAR" (USA):

First US jet fighter in quantity production. About 2,000 "Shooting Stars" were delivered to the US Air Force and the Navy (naval designation, TO-1). Production has been stopped in the meantime. From the first production model (F-80A) the F-80B and *F-80C*, as well as the T-33-A two-seater trainer, were developed. The F-80C, which has a more powerful engine, has six .5-in. machine-guns and can carry two 1,000-lb. bombs and a number of RPs. Wing tip drop tanks.



DE HAVILLAND D.H. 112 "VENOM F.B. 1" (GREAT BRITAIN):

This type was developed from the D.H. "Vampire" and made its first flight in September, 1949. It is in production and will succeed the "Vampire" in the squadrons of the RAF. Negotiations are being finalized for the licence production of the "Venom F.B.1" in France and Italy. Armament: four 20-mm cannon, plus bombs and RPs. Wing tip drop tanks of about 70 Imp.gals. each.

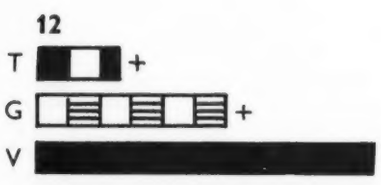


VICKERS-SUPERMARINE "ATTACKER F. 1" (GREAT BRITAIN):

Together with the Hawker "Sea Hawk", the "Attacker" will be the standard carrier-borne fighter of the Royal Navy's air arm. The "Attacker," which first flew in 1946, has four 20-mm cannon in the wing; two 1,000-lb. or four 300-lb. RPs can be carried under the wing. Provision is made for take-off rockets; long-range drop tank under the fuselage.

HAWKER "SEA HAWK" (GREAT BRITAIN):

Carrier-borne fighter built in quantity for the Royal Navy. Derived from the Hawker P.1040 prototype (first flight in 1947) and modified for carrier-operations (folding wings, arrester-hook, etc.). The "Sea Hawk" made its initial flight in the autumn of 1948. Armament: four 20-mm cannon in the nose.



HAWKER P. 1081 (GREAT BRITAIN):

Prototype of a high-speed fighter with a swept-wing and a swept tail unit; intended for quantity production in Australia. First flight in June, 1950. Derived from the P.1052 prototype, which in turn was developed from the "Sea Hawk," but features a swept-wing. Power-plant configuration provides for an afterburner.

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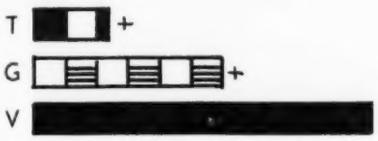
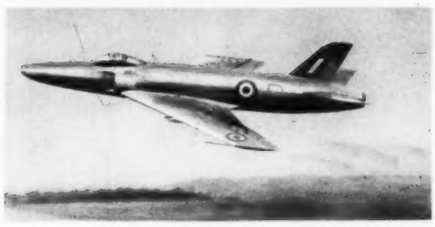
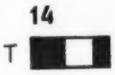




VICKERS-SUPERMARINE 535 (GREAT BRITAIN):

High speed prototype developed from the Supermarine "Attacker" fighter and the Supermarine 510 experimental type (tail-wheel landing gear and swept wing). It made its first flight in 1950, has a nose-wheel landing gear and a long afterburner. Armament: four 20-mm cannon under the wing.

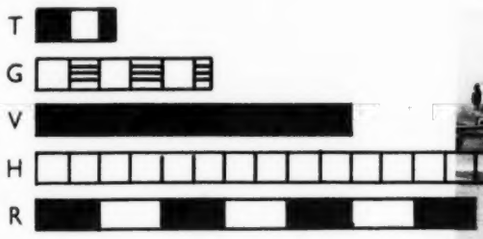
14



BOULTON PAUL P. 111 (GREAT BRITAIN):

Delta-wing experimental aircraft (similar to the Avro 707B) which in view of its powerful engine (R.R. "Nene") is likely to reach very high subsonic speeds. The wing and tail unit leading edges are swept back 45 degrees. First flight of the prototype in late autumn 1950.

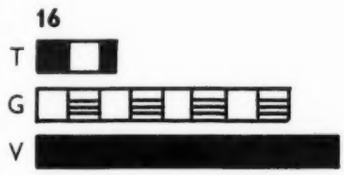
15



DASSAULT MD 450 "OURAGAN" (FRANCE):

Standard fighter of the French Air Force, powered by a Rolls-Royce "Nene" built by the Hispano-Suiza Company. First flight in February, 1949. Armament: four 20-mm cannon in the nose; RPs under the wing. A development of the type has been designed in the form of the MD-452 "Mystère," six of which are on order.

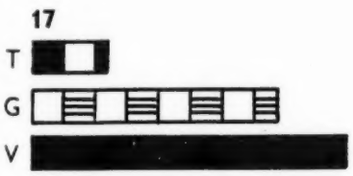
16



ARSENAL VG 90 (FRANCE):

Experimental fighter-bomber designed by the French naval air service. A predecessor was the VG 70 which featured a Junkers "Jumo 004" engine of about 2000 lbs. static thrust. The first prototype of the VG 90 was destroyed in an accident; a second prototype is expected to fly shortly. Projected armament: three 30-mm cannon plus RPs or bombs.

17



NORD 2200 (FRANCE):

Experimental type, optionally a land-based or carrier-based fighter. A single prototype without armament or other military equipment is undergoing its flying trials. Projected armament: three 30-mm cannon plus RPs or bombs.

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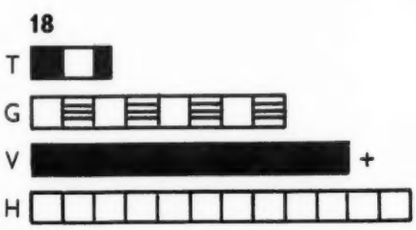


SUD-OUEST SO 6020 "ESPADON" (FRANCE):

The type has been tested in three versions: the first prototype (SO 6020) had the air intake underneath the fuselage, the next (SO 6021) had lateral intakes. The third prototype *(SO 6025)* again has lateral intakes, but its structural design has been simplified. Furthermore, a rocket engine has been added to its Hispano "Nene" gas turbine. Projected armament: six 20-mm or four 30-mm cannon.

19

SVENSKA AEROPLAN SAAB J 29 (SWEDEN):

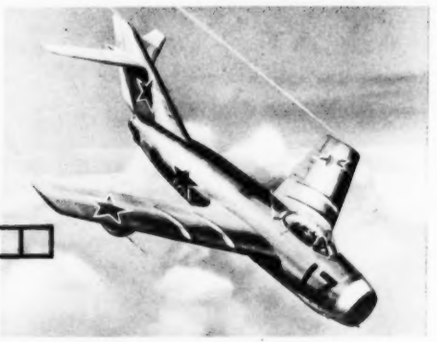
High-performance fighter of the Swedish Air Force, now in quantity production. The aircraft is said to be one of the fastest production fighters in the world (first flight in September 1948). Four prototypes were equipped with a British de Havilland "Ghost," the production version will have a "Ghost" built under licence by Svenska Flygmotor. Armament apparently consists of four 20-mm cannon in the nose and RPs under the wing. Two long-range tanks.

INSTITUTO AEROTECNICO I.Ae. 33 "PULQUI II" (ARGENTINA) :

The Argentine State aircraft factory, at Cordoba, derived this swept-wing (40 degrees) high-speed fighter, under the guidance of the German designer Prof. K. Tank, from the "Pulqui I" (I.Ae.27). The aircraft, which also has a swept tail unit, probably is one of the world's fastest. Armament: four 20-mm cannon in the nose.

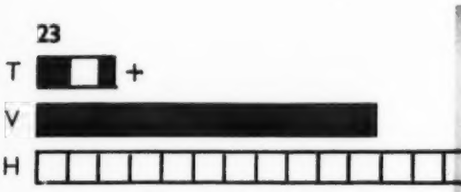
MIKOYAN & GUREVICH MIG-9 (USSR) :

Widely-used production model of the first Russian jet fighter development phase (first flight 1946), metal construction with twin turbines under the fuselage (BMW 003). Armament differs according to tactical use: 43-mm gun plus two 20-mm cannon for ground support or two 30-mm cannon and several .5-in machine guns for fighter duties.



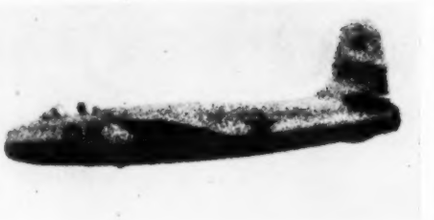
MIKOYAN & GUREVICH MIG-15 (USSR) :

High-performance fighter with swept mid-wing and swept tail unit; very fast and manoeuvrable but of limited range. Probably fitted with centrifugal turbine (Russian copy of the "Nene") and auxiliary rocket motor (BMW 718); tricycle landing gear. Apparently armed with two 30-mm cannon plus two 20-mm cannon, some versions also with a large-calibre gun.



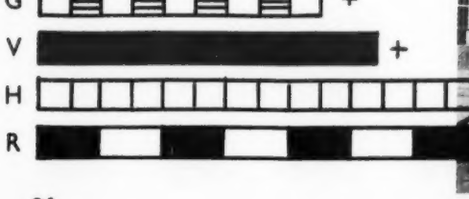
LAVOCHKIN LA-17 (USSR) :

High performance shoulder-wing fighter with swept wing and tail unit, possibly designed as an escort fighter. Tricycle landing gear. Powerful engine, apparently also of centrifugal type. Armament: several 20-mm or 30-mm cannon.



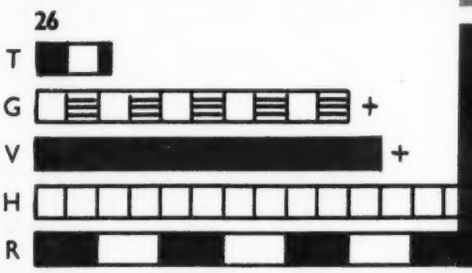
YAKOVLEV YAK-17 (USSR) :

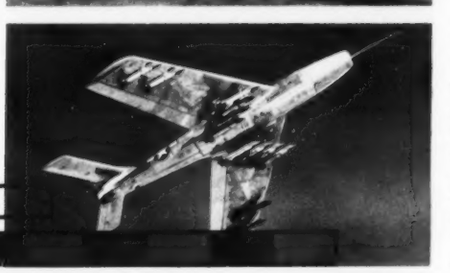
Straight low-wing monoplane with powerful engines, nose-wheel gear; nick-named "Red Thunderjet." It is reported that a swept-wing version of the type has been developed. Armament: several 20-mm or 30-mm cannon.



REPUBLIC F-84E "THUNDERJET" (USA) :

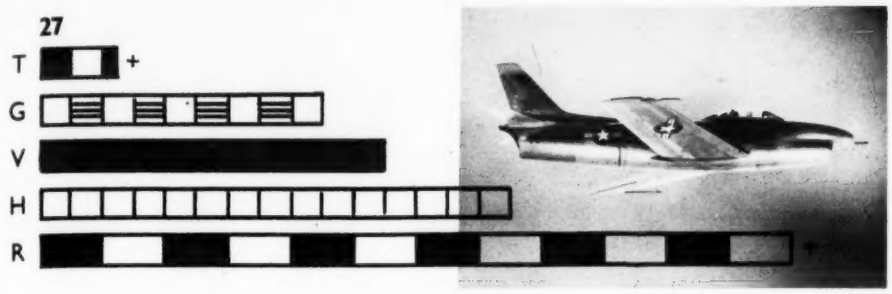
Standard fighter and ground support aircraft of the USAF. Developed from the XP-84 (prototype, first flight in February 1946), F-48A (pre-production series), F-84B (first production), F-84C and F-84D, the aircraft has a more powerful engine and a longer fuselage. Pressurized cabin and ejector seat. Armament: six .5-in. machine-guns (including four in the nose, two in the wing) and twelve 5-in. HVAR rocket projectiles plus two 1200-lb. "Tiny Tim" rockets, or 32 5-in. HVAR rockets. Two wing-tip long-range tanks of 191 Imp.gals. each.





REPUBLIC F-84F "THUNDERJET" (USA) :

This development of the F-84E, with an even more powerful engine, swept-wing and swept-tail unit, though with an unchanged fuselage, was temporarily designated YF-96A, but was later renamed F-84F (first flight in 1950). Like its predecessors it seems to be destined both for interception and escort duties and for ground support. It carries at least 24 HVAR five-inch rockets in addition to its guns. An experimental version equipped with an Armstrong-Siddeley "Sapphire" engine of 7,200-lbs. static thrust will shortly begin its trials.

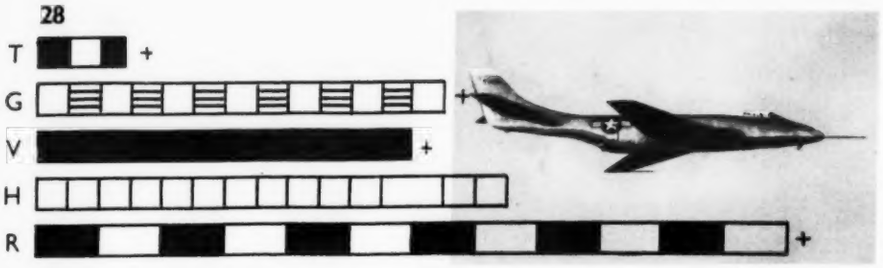


NORTH AMERICAN F-86D "SABRE" (USA):

Swept-wing high-performance fighter with a swept tail-unit (35 degrees) now being produced in large numbers for the USAF. Derived from the XF–86 prototype (first flight October 1947), the F–86A (preliminary production, now discontinued) and the F–86C, by the installation of a more powerful engine (J–47 with afterburner) in a lengthened fuselage. Very long range (2,300 miles with auxiliary tanks) but relatively light armament (six .5-in machine-guns plus 16 HVAR 5-in. rockets). Pressurized cockpit and ejector seat. A naval fighter version of the F–86D has been ordered under the designation F2J–1. A special version designated F–86E features an "all-flying tail" and automatic control boost.

Number	MAKER AND MODEL	POWER PLANT		DIMENSIONS			Normal gross weight	PERFORMANCE			
		Maker and Model	Total thrust	Span	Length	Wing area		Maximum speed	Rate of climb	Service ceiling	Range
			lbs.	ft.	ft.	sq. ft.	lbs.	knots	ft./min.	ft.	NLM
1	**De Havilland D.H. 100 "Vampire F.B. 5"**	1 De Havilland "Goblin 2"	3100	38	30.8	262	10500	435	4200	48500	990
2	**Yakovlev Yak-15 B**	1 Jumo 004 (Chelomei)	3080	appr. 33	appr. 29.5	—	approx. 8800	435	—	—	—
3	**Svenska Aeroplan J 21 RA**	1 De Havilland "Goblin 2"	3000	38.1	34.6	240	9350	430	—	40500	—
4	**McDonnell FH-1 "Phantom"**	2 Westinghouse J-30-WE-20	3200	40.8	38.8	appr. 270	10000	430+	4000+	36000+	865+
5	**Chance Vought F6U-1 "Pirate"**	1 Westingh. J-34-WE-30 A	3200+	32.9	37.7	—	11300	480	8000+	38000	—
6	**Avro 707 B**	1 Rolls-Royce "Derwent"	3500	33.0	30.5	200	8800	—	—	—	—
7	**North American FJ-1 "Fury"**	1 Allison J-35-A-5	4000	38.1	33.6	appr. 270	12500	480	5000+	39500+	1000+
8	**Lockheed F-80 C "Shooting Star"**	1 Allison J-33-A-23	4600+	38.9	34.5	237	15300	520	5100	45000+	—
9	**De Havilland D.H. 112 "Venom F.B. 1"**	1 D.H. "Ghost 50"	5000	41.8	31.4	279	12100	510	—	50000+	—
10	**Vickers-Supermarine "Attacker F. 1"**	1 Rolls-Royce "Nene 3"	5000	36.9	37.5	226	11700	510	6250	48500	1000+
11	**Hawker "Sea Hawk"**	1 Rolls-Royce "Nene 4"	5000	39.0	40.0	278	—	—	—	—	—
12	**Hawker P. 1081**	1 Rolls-Royce "Nene"	5000+	31.5	37.3	258	13200+	540+	—	—	—
13	**Vickers-Supermarine 535**	1 Rolls-Royce "Nene"	5000+	31.7	42.9	295	13200+	540+	—	—	—
14	**Boulton Paul P. 111**	1 Rolls-Royce "Nene"	5000	33.5	26.1	200	9600	—	—	—	—
15	**Dassault MD 450 "Ouragan"**	1 Hispano-Suiza "Nene"	5000	39.9	35.1	241	12300	510+	8000+	50000	700+
16	**Arsenal VG 90**	1 Hispano-Suiza "Nene"	5000	39.3	44.3	330	17600	485+	—	33000+	—
17	**Nord 2200**	1 Hispano-Suiza "Nene"	5000	39.3	44.3	328	17350	500	4500	—	—
18	**SNCA-SO 6020 "Espadon"**	1 Hispano-Suiza "Nene"	5000	34.8	48.2	280	approx. 17600	510+	5900	40000	—
19	**Svenska Aeroplan SAAB J 29**	1 D.H. (SFA) "Ghost"	5000	36.1	39.8	258	—	567	—	—	—
20	**Instituto Aerotecnico I.Ae. 33 "Pulqui II"**	1 Rolls-Royce "Nene 2"	5000	34.8	38.1	270	12200	560	5900	50000	—
21	**Mikoyan-Gurevitch Mig-9**	2 BMW-Chelomei M-003	5060	40.4	36.1	—	—	460	—	—	—
22	**Mikoyan-Gurevitch Mig-15**	1 Chelomei ("Nene" ?)	5060	32.8	32.8	—	—	560	—	50000	—
23	**Lavotchkin La-17**	1 Chelomei ("Nene" ?)	5100+	40.0	37.1	—	—	540	—	50000	—
24	**Yakovlev Yak-17**	1 Chelomei ("Nene" ?)	5100+	—	—	—	—	—	—	—	—
25	**Republic F-84 E "Thunderjet"**	1 Allison J-35-A-17	5000+	37.4	38.0	—	19800+	540+	4500+	50000	1200+
26	**Republic F-84 F "Thunderjet"**	1 Allison J-35-A-25	5200+	34.0	38.0	—	22000+	550+	—	50000	1200+
27	**North American F-86 D "Sabre"**	1 General Electric J-47	5200+	37.0	41.0	—	19800+	560	—	50000	1200+
28	**McDonnell XF-88 "Voodoo"**	2 Westinghouse J-34-WE-22	6000+	39.7	54.1	—	29700	600+	6000+	—	1500+
29	**Lockheed XF-90**	2 Westinghouse J-34-WE-22	6000+	40.0	55.0	—	29700	600+	6000+	50000	1500+
30	**Republic XF-91**	1 General Electric J-47 (and 4 rocket engines)	5200+ (3200)	30.0	45.0	—	—	600+	—	50000+	—
31	**Convair XF-92 A**	1 Allison J-33-A-23	5400	31.3	41.3	240	13000	—	—	—	—
32	**Grumman F9F-5 "Panther"**	1 Pratt & Whitney J-48-P-4	6250	38	42	—	15700	540+	9000	58000	—
33	**McDonnell F2H-2 "Banshee"**	2 Westinghouse J-34-WE-34	6300+	41.5	40.0	appr. 280	17600+	510+	9000+	50000+	1000+
34	**Chance Vought F7U-1 "Cutlass"**	2 Westinghouse J-34-WE-32	6400+	—	—	—	—	—	—	—	—
35	**Gloster "Meteor F. 8"**	2 Rolls-Royce "Derwent 5"	7200	37.2	44.6	350	—	520	—	—	—
36	**Saunders-Roe SR/A1**	2 Metrovick "Beryl"	7700	46.0	50.0	415	16200	430+	—	—	—
37	**Yakovlev Yak-15 B (Trainer)**	1 Jumo 004	3080	appr. 33	appr. 33	—	approx. 8800	435	—	—	—
38	**De Havilland D.H. 115 "Vampire Trainer"**	1 D.H. "Goblin 3"	3350	—	—	—	11030	470	—	40000	730+
39	**De Havilland D.H. 113 (Vampire Night Fighter)**	1 D.H. "Goblin 4"	3500	38.0	34.6	—	—	—	—	—	—
40	**Fiat G. 80**	1 D.H. "Goblin 35"	3500	—	—	—	11000	475	—	44000	730
41	**Lockheed T-33 A**	1 Allison J-33-A-23	4600+	38.9	37.7	227	14440	510+	5100+	46000+	—
42	**De Havilland D.H. 112 "Venom N.F. 2"**	1 D.H. "Ghost"	5000	41.8	34.6	278	13200+	510+	—	50000	—
43	**Lockheed F-94 C**	1 Pratt & Whitney J-48	6250+	38.9	40.1	227	approx. 15900	520+	—	—	—
44	**Douglas F3D-1 "Skyknight"**	2 Westinghouse J-34-WE-38	6400	50.0	45.0	—	approx. 22000	510+	—	40000+	—
45	**Gloster "Meteor T. 7"**	2 R.R. "Derwent 5"	7000	37.2	43.5	350	13900	510+	8000	46000	—
46	**Gloster (AWA) "Meteor N.F. 11"**	2 R.R. "Derwent 8"	—	43.0	48.5	373	—	—	—	—	—
47	**Northrop F-89 A "Scorpion"**	2 Allison J-35-A-21	10000+	50.0	50.0	562	32500	520+	—	40000+	1600+
48	**Avro-Canada CF-100 "Canuck"**	2 R.R. "Avon"	12000	52.0	52.5	—	approx. 27000	510+	—	—	—

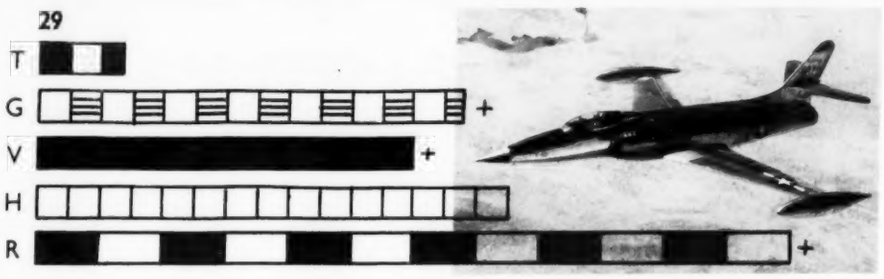
28



McDONNELL XF-88 "VOODOO" (USA):

Prototype of a twin-engined penetration fighter, escort fighter or ground attack aircraft of maximum range and speed; equipped with afterburners (first flight 1949). Sweep-back of 35 degrees on wings and tail unit; pressurized cockpit and ejector seat.

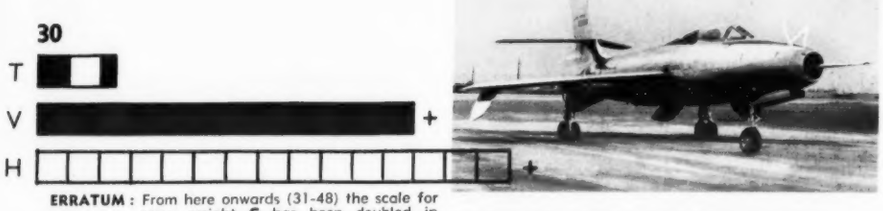
29



LOCKHEED XF-90 (USA):

Prototype of a twin-engined penetration fighter of maximum range and speed (first flight, June 1949). Fitted with afterburners (and with two take-off rockets), the type no doubt attains supersonic speeds. Strongly swept wings and tail unit (35 degrees); pressurized cockpit and ejector seat.

30



REPUBLIC XF-91 (USA):

Prototype of an upper-atmosphere fighter (first flight May 1949). Equipped with a powerful gas-turbine engine plus afterburner plus four rocket motors and featuring an inversely tapering swept-wing of variable incidence, the XF-91 seems to be capable of reaching phenomenal operational heights in record time and of flying at supersonic speeds. Tricycle landing gear with tandem main wheels retracting outwards into the extremely thin wings. Pressure cockpit with ejector seat.

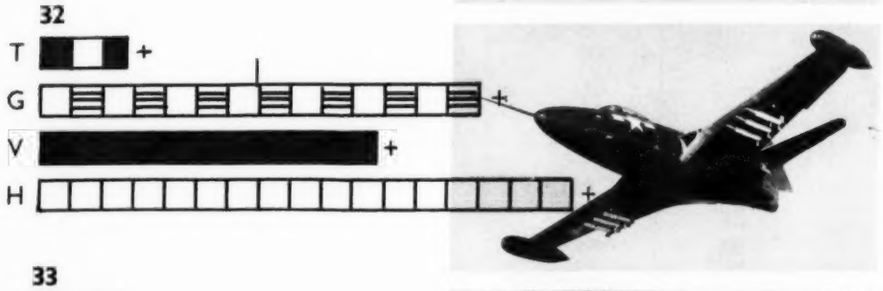
ERRATUM: From here onwards (31-48) the scale for gross weight **G** has been doubled in error (10 mm = 1000 kg), whereas the original scale (10 mm = 2000 kg) has been maintained for thrust **T**. Vertical lines mark the true comparative value of **G**.

31

CONVAIR XF-92A (USA):

Experimental fighter featuring a wing of delta configuration (first flight February 1949). The leading edges of the wing and the vertical fin are arranged at an angle of 30 degrees to the direction of flight and thus form an angle of 60 degrees with the straight trailing edges. Pressurized cockpit with ejector seat. Probably equipped with rocket motors, to enable it to fly at transonic speeds.

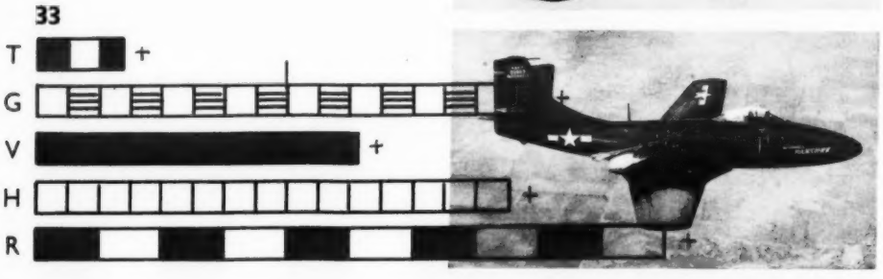
32



GRUMMAN F9F-5 "PANTHER" (USA):

Carrier-borne fighter and ground-support aircraft of the US Navy. Developed from the F9F-2, F9F-3 and F9F-4 (first flight November 1947) by successive increases in engine power, lengthening of the fuselage and modification of the air-intakes. Several hundred are in operation. Ejector seat; fixed wing-tip fuel tanks; folding wings; landing flaps on trailing edge *and* on leading edge of the wing. Armament: cannon and rocket projectiles.

33



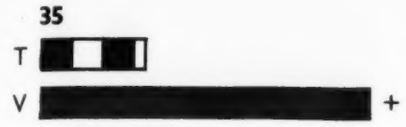
McDONNELL F2H-2 "BANSHEE" (USA):

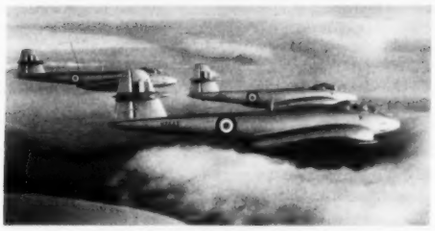
Twin-engined carrier-fighter, probably now equipped with afterburners. In service in considerable numbers. Folding wings; pressurized cabin; fuel capacity, 4,170 Imp.gals. plus wing tip drop tanks. Armament: four 20-mm cannon in the lower part of the nose.

34

CHANCE VOUGHT F7U-1 "CUTLASS" (USA):

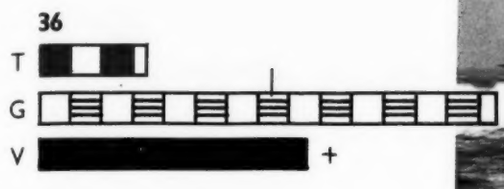
Twin-engined carrier-fighter of the US Navy (first flight September 1948). Afterburner, pressurized cockpit and ejector seat; "flying-wing" compromise with vertical fins on the wing. Armament: four to six 20-mm cannon. A small number of a later version is on order.

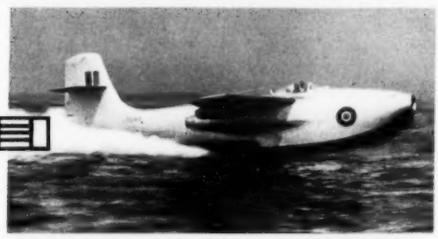




GLOSTER "METEOR F. 8" (GREAT BRITAIN):

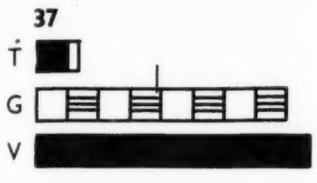
Latest and most modern addition to the "Meteor" single-seater fighter and fighter-bomber family, featuring a long fuselage and a modified tail unit; twin-engined; in production. Predecessor types were the F. 9/40 (first flight March 1943) and "Meteor F. 4." Normal fuel capacity 420 Imp.gals.; three auxiliary tanks under fuselage and wings. Armament: four 20-mm cannon plus rocket projectiles or bombs.

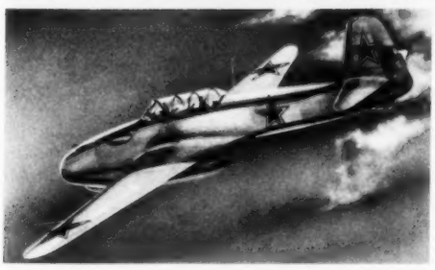




SAUNDERS-ROE SR-A1 (GREAT BRITAIN):

Third prototype of a twin-engined sea-going single-seater fighter flying-boat (first flight July 1947). The first two prototypes crashed during tests, but the aircraft nevertheless disclosed an exceedingly satisfactory performance. It is unlikely that it will be put into production.

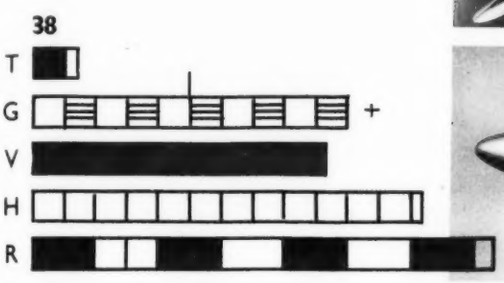


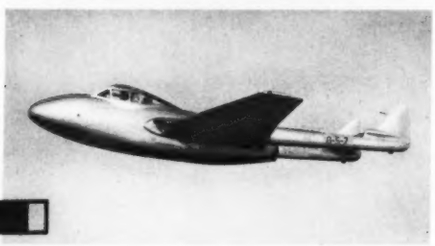


II. Two-seaters

YAKOVLEV YAK-15B (USSR):

First jet propelled two-seater trainer of the Soviet Air Force. In service in considerable numbers in a tricycle version. The cockpit of the pupil is arranged ahead of the pilot's seat, now occupied by the instructor.



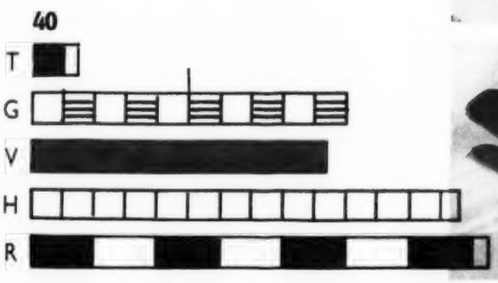


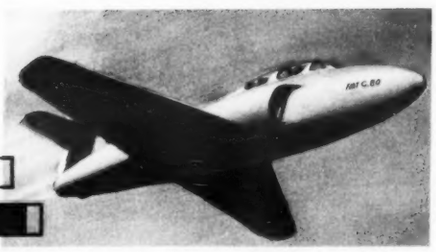
DE HAVILLAND D.H. 115 "VAMPIRE TRAINER" (GREAT BRITAIN):

Side-by-side trainer derived from the D.H. 113 two-seater night-fighter; pressurized cockpit. Wing and equipment correspond to those of the original D.H. 100 "Vampire 5" fighter-bomber; other major components are also interchangeable. The type, which may be converted for combat use in an emergency, has aroused considerable interest in all countries which have adopted the "Vampire." It made its first flight in November 1950.

DE HAVILLAND D.H. 113 "VAMPIRE NIGHT FIGHTER" (GREAT BRITAIN):

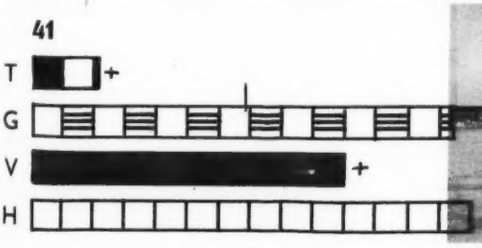
Two-seater night fighter derived from the D.H. 100 "Vampire" by widening and lengthening the fuselage. Staggered seats, side-by-side, pilot to port forward and radar operator to starboard rear; radar equipment in fuselage nose. The internal cabin lay-out strongly resembles that of the D.H. 98 "Mosquito" bomber, which enabled proven items of the latter aircraft to be taken over without change. Following its first flight in August, 1949, the aircraft was ordered by several nations.





FIAT G. 80 (ITALY):

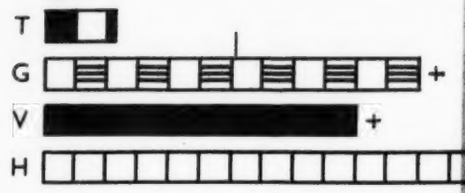
Two-seater trainer project with ejector seats in tandem, designed by Professor Gabrielli. The fuselage consists of three elements, bolted together at four points each, so that the nose carrying the military equipment is readily interchangeable. The de Havilland "Goblin 35" and the Rolls-Royce "Nene" are alternative power plants; prototype under construction.



LOCKHEED T-33A (USA):

Two-seater training version of the Lockheed F-80C "Shooting Star," designated TO-2 by the US Navy. Seats in tandem, the pupil forward and the instructor in the rear. Originally the aircraft was designated TF-80C. Its fuselage had to be lengthened by about 3 ft. and the fuel capacity of the fuselage tank reduced somewhat. The nylon fuel tanks in the wing carry a little more than those of the F-80. Armament: two .5-inch machine-guns plus rockets and practice bombs. Auxiliary tanks optional.

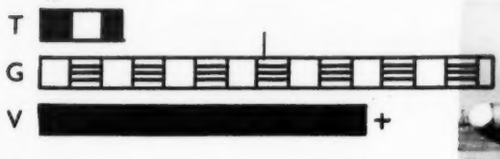
42



DE HAVILLAND D.H. 112 "VENOM N.F. 2" (GREAT BRITAIN):

Two-seater night fighter version of the D.H.112 "Venom F.1" day-fighter, featuring a somewhat lengthened fuselage to house the radar equipment. The first flight of the aircraft took place in August 1950 and quantity production has probably started. Armament: several cannon, probably 20-mm.

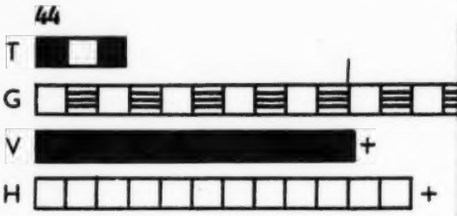
43

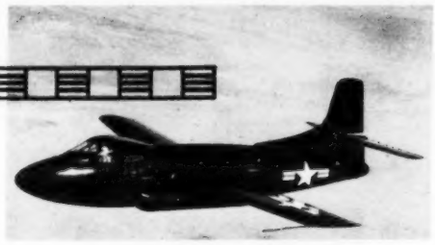


LOCKHEED F-94 C (USA):

This all-weather fighter (temporarily designated F–97) was derived from the Lockheed T-33 two-seater trainer and is now in large-scale production. The type has search radar equipment in the nose and an afterburner in the tail. It is planned to create a ground support version by replacing the second seat with a large fuel tank. Armament: apparently four 20-mm cannon. Long-range wing tip tanks.

44

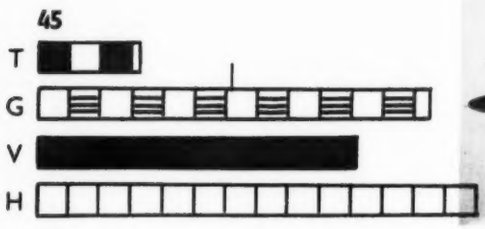




DOUGLAS F3D-1 "SKYKNIGHT" (USA):

Twin-engined carrier-based night and all-weather fighter with seats side-by-side and extensive radar and wireless equipment. Folding wings with long-range tanks at the junction of wing centre section and outer panels. The type has an emergency exit (chute) in the cabin floor for bailing out at high speeds as well as an emergency hatch in the canopy in the event of ditching; pressurized cabin. The aircraft features a satisfactory top speed, outstanding climbing performance and very long range. Armament: four 20-mm cannon, rocket projectiles or bombs.

45



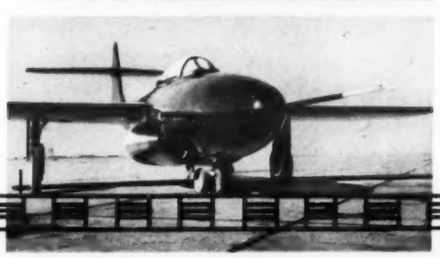
GLOSTER "METEOR T. 7" (GREAT BRITAIN):

Two-seater trainer version of the "Meteor F.4" twin-engined standard fighter; longer fuselage to accommodate a second seat. The pupil is seated forward. Since the first flight of the "Meteor T.7" (March 1948), the type has been placed in quantity production for the RAF, as well as for the Egyptian, Belgian, Danish and Netherlands Air Forces. Normal fuel capacity, 325 Imp.gals.; auxiliary long-range tanks.

46

GLOSTER "METEOR N.F. 11" (GREAT BRITAIN):

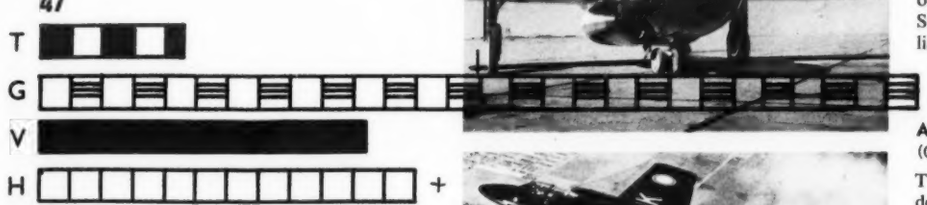
Two-seater night fighter developed by the Armstrong-Whitworth company (like Glosters a branch of the Hawker-Siddeley Group) from the "Meteor T.7" two-seater trainer and the "Meteor F.8" single-seater fighter; in production at the plant of Armstrong-Whitworth-Armament: four electrically-fired 20-mm cannon in the wing. Complete radar equipment.



NORTHROP F-86 A "SCORPION" (USA):

Two-seater all-weather fighter with pressure cabin and ejector seats in tandem (first flight August 1948). The pilot's cockpit is forward, that of the radar-operator to the rear. The type is in production. Six 20-mm cannon are located in the nose. Auxiliary long-range tanks at the wing tips.

47



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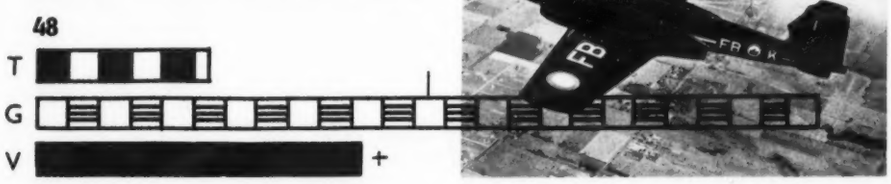


AVRO-CANADA CF-100 "CANUCK" (CANADA):

Twin-engined all-weather fighter of very long range, destined for the Royal Canadian Air Force. The type is very versatile and is suitable for ground support, naval support and long-range reconnaissance. The prototype, powered with two Rolls-Royce "Avon" engines, already is one of the most powerful fighters in the world. Production models will be equipped with Avro-Canada "Orenda" engines which are at least as powerful, if not more powerful. Armament: probably four 30-mm cannon in the nose.

Red Operational Fighters Are Equal to West's *

Both of the World Wars have featured their quota of aviation "scares": World War I saw Anthony Fokker's products temporarily affording Germany considerable superiority over her adversaries in the air and, nearer at hand, the Japanese "Zeke" and German Focke-Wulf Fw 190 fighters created similar situations in World War II. The appearance of Russia's MiG-15 can be compared with earlier "scares," and it is perhaps fortunate for the Western Powers that this modern combat aircraft has been met with over Korea in modest numbers.

Implications of the MiG-15 are profound. Reports from Korea indicate that the MiG-15 is capable of outflying such widely-used machines as the Lockheed F-80 "Shooting Star," Republic F-84 "Thunderjet" and Grumman F9F "Panther" and it takes the North American F-86 "Sabre" to meet the Russian fighter on a basis of parity. Even then, the superior speed of the USAF fighter is offset by the superior manoeuvrability of the MiG-15—a timely warning that the Western Nations have no exclusivity in the design of *really* modern combat machines.

The MiG-15 has now replaced the majority of the piston-engined La-9, La-11 and Yak-3 fighters that, until recently, were based in Eastern Germany, and many reports indicate that the runways of airfields at Grossenhein, Brandis, Laerz and Finow are lined with MiG-15 fighters. Intelligence photos indicate that the MiG-15s based in the Soviet Zone of Germany are of a later production model than those that have been encountered over Korea, embodying numerous refinements which may indicate an even better performance than was originally supposed. The earlier production MiG-15s, based at Autung airfield, just North of the Yalu river, are busily engaged in sounding out the qualities of USAF fighters, information that is undoubtedly being transmitted post-haste to Moscow.

It is now known that this fighter's 35°-swept mid-wing spans thirty-three feet—which is about the same as the MiG-15's length—but the question of the type of turbojet installed is still unresolved. Many reports have indicated the use of a centrifugal compressor type unit based on the Rolls-Royce "Nene." Such a turbine would undoubtedly prove attractive to the Russians on the basis of its greater simplicity and sturdier qualities than to-day's axials. It would also provide sufficient power to afford the MiG-15 its 640–650 m.p.h. maximum speed. However, there are those who consider that, owing to the use of a nose intake, some form of axial-flow unit is installed. Such arguments are based on the fact that centrifugal units, such as the "Nene" with its double-sided impeller, require a plenum chamber to supply sufficient air to both sides of the impeller, and nose entries afford many problems when applied to this type of engine, unless the intake is close to the turbojet. Consequently, side intakes are almost universal for "Nene"-powered fighters, though notable exceptions are the Dassault "*Ouragan*" and Kurt Tank's "*Pulqui II*" which both combine "Nene" centrifugal unit and nose intake.

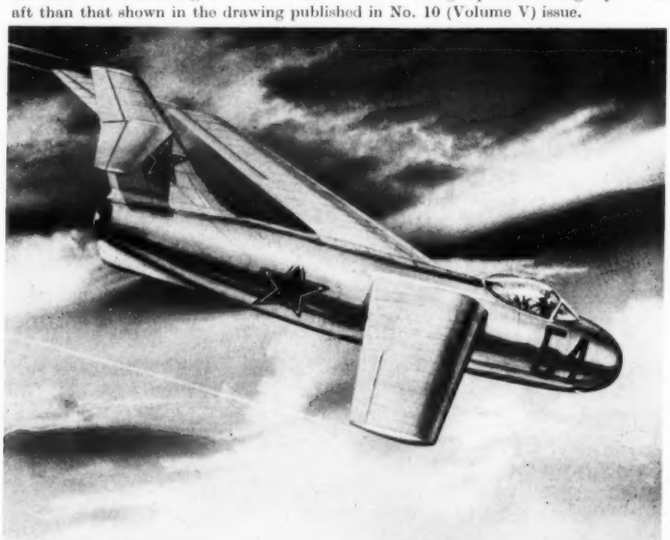
The ability of the MiG-15 to draw away from its adversaries, and the puffs and streams of white smoke that issue from its tail orifice while so doing, may indicate the use of some form of rocket boost. It is conceivable, therefore, that the Russians have developed the German B.M.W.003R unit—which consisted of a standard B.M.W. 003A axial turbojet with the addition of a B.M.W.718 bi-fuel liquid rocket giving a thrust of about 3.300 lbs. for a period of three minutes—to give appreciably more power than the original at an acceptable production standard. The only known Russian production axial-flow unit that might afford sufficient power for the MiG-15 is the M-012H (described in issue No. 11, 1950, of *Interavia Review*,) but this unit's length of 177 inches would appear prohibitive.

A comparison of the MiG-15 and the F-86 "Sabre" reveals that it is on the question of wing, span and power loadings that the Russian and American schools of thought differ most radically. While the Reds seem to believe that wing loadings must be kept down at all cost in order to permit high accelerations in turns and a high rate of climb— a goal achieved by keeping weight and internal equipment to a minimum and by providing reasonably generous wing areas—the Americans have considered their prime requisite to be speed, and this has been obtained at the expense of manoeuvrability at altitude. Thus, although the F-86 has the advantage of a higher limiting Mach number, the MiG-15 has a far smaller turning circle, and its greater manoeuvrability would enable its pilot to bring his guns to bear more

* A comprehensive survey of the latest Soviet combat aircraft appeared in issue No. 10, Vol. V, 1950, of *Interavia Review*. The present article deals with the qualities of the jet fighters in large-scale operational service with the Soviet Air Force.

This new illustration of the MiG-15, prepared from the latest photographic evidence, shows one of the later production model MiG-15s. Notable features are the four boundary layer fences fitted to the upper surfaces of the wing, the external whip aerial and the air brakes fitted to the rear fuselage near to the exhaust orifice. A bulge under the starboard wing is believed to be a small fuel tank. The cannon armament is semi-externally mounted, the cowled barrels of the guns running along the underside of the nose. A bullet-shaped fairing on the tailplane has been seen on recent machines.

The Lavochkin La-17 fighter incorporates recently revealed details such as the ventral fin under the rear fuselage. It is now known that the wing is positioned slightly farther aft than that shown in the drawing published in No. 10 (Volume V) issue.



easily than the American pilot, although the higher limiting Mach should provide a steadier gun platform.

The armament of the MiG-15 appears to differ between aircraft considerably. First production models carried one 30-mm and one 20-mm cannon, whereas some machines over Korea carry a cannon of at least 37-mm and machines seen in Germany appear to embody two 30-mm and two 20-mm weapons, any of which combinations is vastly more powerful than the .5-inch guns of opposing USAF fighters, although the ammunition supply must consequently be inferior.

The latest MiG-15s have four boundary layer "fences" on the upper surfaces of the wings, and their air brakes—for greater combat flexibility—are attached to the sides of the rear fuselage, near the tail orifice. The use of a whip aerial on such a high-speed machine is rather puzzling.

A second first line fighter is going into service with the Soviet Air Force in considerable numbers: the Lavochkin La-17. It is a rather larger, sleeker machine than the earlier MiG-15 and is not yet as widely used as the MiG. Spanning approximately 40 feet and having a length of 37 feet, the wings of the La-17 are not quite so sharply swept as those of the MiG-15, possessing a sweep back of 30°. All members of the undercarriage retract into fuselage housings, and in view of the fact that the wing is entirely free of armament and wheel housings and can therefore hold fuel tanks, plus the Lavochkin's sleeker and more rotund fuselage, it is likely that this fighter has an appreciably longer range than the essentially short-range-interceptor type MiG-15. Its duties may therefore include those of an escort fighter for tactical bombing formations.

Backing these ultra-modern fighters are appreciable quantities of earlier fighter designs such as the MiG-9 and Yak-15. The latest variant of the Yak-15, which is fitted with a nosewheel undercarriage, has a maximum speed of 505 m.p.h. at altitude and, although obsolescent in Western eyes, should prove most useful for ground attack duties. This version, tentatively known as the Yak-15B, is flying with both the original curved fin and rudder and a new square-cut empennage (shown in our drawing) and armament is now known to have been increased to two cannon, probably of 30-mm calibre.

Following the example of the USA (Lockheed T-33) and Great Britain (Gloster "Meteor 7" and de Havilland "Vampire Trainer"), Soviet Russia has adapted one of her earlier jet fighters into a two-seater jet fighter trainer. The aircraft is a special version of the Yak-15B single-seater, in which a cockpit for the pupil is installed ahead of the original cockpit. Pupil and instructor are enclosed in a "greenhouse" style canopy. The type, which features a nose-wheel undercarriage, is in wide use in the Red Air Force.

It is unquestionable that, should an open clash develop between East and West, the machines described and illustrated here will play a major part in the Russian offensive. They are well-designed, hard-hitting combat aircraft (excepting the Yak trainer) obviously at least equal to the operational jets of the USA and Britain. What is more, they are in squadron service in vast numbers. There is little solace in the fact that much more powerful, faster and longer-ranging jet fighters are "coming along" in the West, for there is no telling what the Russians may have on their drawing-boards or in the prototype stage. It is only to be hoped that the Western powers will not underestimate the capabilities of Russian designers as they have tended to do hitherto.

A Jet Test Pilot Talks About His Job

BY OUR SPECIAL CORRESPONDENT

The day I visited Hawker's aerodrome at Langley, Squadron-Leader T. S. Wade, D.F.C., A.F.C., Chief Test Pilot of Hawker Aircraft, Ltd., was preparing for a trip to the United States to fly the latest American jet aircraft. For a little while we sat together in his green-carpeted office with its four telephones, while he quietly told me that there really was nothing out of the ordinary in testing jet aircraft.

In point of fact, this had been the theme of an article which "Wimpy" (as he is known to his friends) wrote four years ago. He is most emphatic that there is nothing miraculous about jet aircraft, it is only that their huge power gives them extra speed and climb. As is fairly generally known now, they are even simpler than propeller-driven aeroplanes in many respects. The engine instrumentation and the engine controls are fewer and require less attention. There is no propeller control to bother about; but, on the other hand, there is the enormous fuel consumption, which means that the fuel gauges must be watched continuously. Furthermore, a good deal of mental arithmetic has to be done to decide under certain wind conditions whether it is better to travel low down or high up. For instance, although the fuel consumption improves with altitude, a 50 m.p.h. head wind may make it advisable to fly low down at a higher fuel consumption. In this respect the Americans have been more methodical than the British so far, and pilots are issued with charts from which they can select the most favourable height and speed to suit the range requirements and wind conditions.

Squadron-Leader T. S. ("Wimpy") Wade, D.F.C., A.F.C., Chief Test Pilot for Hawker Aircraft Ltd.

There is, of course, no torque reaction to worry about and, since designers try to make the thrust line coincide with the centre of resistance, no appreciable change of trim occurs when opening the throttle. There is, of course, no swing tendency at take-off.

When questioned as to the preliminary trials, the high-speed taxying and short hops, where the lower initial thrust of the jet requires more space, Wade said that this scarcely mattered, since the huge runways at Boscombe Down, now some 3,500 yards in length, amply cater for this deficiency in acceleration. He said that he was, frankly, much happier making the initial trials of a jet aeroplane than of a piston-engined type, because it was so much simpler. A jet engine had no propeller and constant speed units to go wrong, supercharger gears to give trouble, boost pressures to watch—it either worked or it did not.

As we went on to discuss the effects of power, he mentioned one further difference between the jet and piston-engined aircraft, which was the way in which greater anticipation of power needs was required on the

Squadron-Leader Wade tests the P. 1081 prototype, latest addition to the Hawker fighter family.

approach to land. It is necessary to realise much more quickly when the engine will have to be opened up because of the slower build-up of thrust.

It is no longer a question, considers Wade, of the aero-dynamic expert choosing his "lines," so much as the engineer designing a wing that is thin enough and strong enough to give the speed and take the load. Another example of how the engineer is coming into his own, is the fact that delicately designed control balances and tabs are virtually useless at these high Mach numbers. Instead, power-boosted or power-operated controls are essential and the designer has to concentrate upon producing an aileron that is strong enough to be pushed up hard and far into the air stream. This becomes particularly apparent with wing dropping due to compressibility stall at very high speeds. The air flow has already broken away from the wing, and no amount of balancing can do the trick. It is exactly as Wade said, the aileron must be big enough and the power controls strong enough to push it up into the air stream away from the turbulent area so that it can be effective. Longitudinal control effects are similar, although here it can be assisted by the adjustable tailplane.

The effect of sweepback—which, I would guess, delays the onset of compressibility troubles by some 10% on a given airframe/wing-section combination—is to make the aeroplane more manageable at the higher speeds, as everybody knows, but it does not eliminate the troubles. At low speed it has some big effects, although it is less troublesome from the point of view of wing dropping than one had been led to expect. In the Hawker designs, Wade said that the swept wings were quite as manageable as the other high speed types and there was no trouble about the stall. Sweepback did, of course, lead to "Dutch roll," that curious wallowing instability that has appeared in recent years. In the Hawker types, at any rate, it is only a temporary phenomenon and usually damps itself out quite quickly after the circumstances causing it have stopped. Because of the sweepback, as speed falls off the rudder becomes less and less effective for correcting drift on the approach and, instead of imparting yaw to the aeroplane, it causes a wing to go down when applied. The reason for this is the "dihedral effect" of the sweepback which, as one wing is advanced when the rudder is applied, causes a larger span to be presented to the airflow, thereby lifting that wing. The total effect of this is that as the airspeed is reduced, more and more bank must be held off when making a turn, until there comes a point where there may be insufficient aileron control available to counteract the bank which the aeroplane takes up on its own account and the turn becomes a "slip-on." Therefore, with swept-back aeroplanes, it is necessary to make an accurate, long, straight approach and the banked turn-in-to-land (known as the "Spitfire Approach" in the RAF) is no longer applicable.

Asked about G-suits, Wade said that he personally found them uncomfortable and of little use. This may have been his own physique which, when tested on a centrifuge, proved unusually robust, or it may have been also that he automatically tenses his muscles as he feels the onset of blacking-out. He admitted that during his aerobatic displays at Farnborough, when he was anxious to keep in sight of the airfield, he occasionally blacked out for brief periods, although normally when doing high speed manoeuvres the onset of deafness was sufficient warning to let him ease off before losing sight. He did not think that the addition of an accelerometer (this is not an operational requirement in British regulations) would help a fighter pilot much, since he is already too busy with his Machmeter and contents gauge. Manoeuvring at high altitude was another matter and there some G-stall warning device might well become necessary in future.

Wade mentioned that nearly five years ago he had advocated the combined A.S.I./Machmeter to ease the pilot's problems but it was only just coming into use in this country—although it had been standard for some time in the USA. This subject naturally led to the question of high or low wing loadings. He was emphatic that speed is by no means everything: the plotting of a curve of pursuit at 40,000 ft. for a fighter trying to overtake a fast bomber *without exceeding his limiting Mach number and without entering a G-stall is fantastic.* It could be done mathematically, but it was pretty hard luck on the pilot trying to do it in space! Undoubtedly the aeroplane with the low wing loading, given equal speed, was the one that would win every time. Therefore, let us have enormous power, rapid interception, and no external decorations such as wing tip tanks, etc. In other words, use your power to reach the enemy quickly without overloading the aeroplane.

Asked about the MiG-15 and the Lavochkin fighters, Wade shrugged his shoulders and said he remembered the Me-110 and Fw 190 fairy stories. Each was credited with the most fantastic ability until our own pilots had tried them out and found them to be good aeroplanes—and with some striking failings. That would seem to be a very fair summing-up until such time as our pilots can fly these rumoured types.

"Wimpy" Wade in the Hawker P.1040 fighter, prototype of the Hawker "Seahawk" carrier-borne fighter.

Jet Maintenance

BY JAMES HAY STEVENS, LONDON

Before going on to write about the maintenance of jet engines I had better point out that this article will deal principally with centrifugal compressor engines. The reason for this is not bias but lies in the fact that experience of axial engines in Great Britain has so far been limited to experimental and pre-production types—and no true picture of maintenance values can be obtained until an engine has been in everyday use for a number of years.

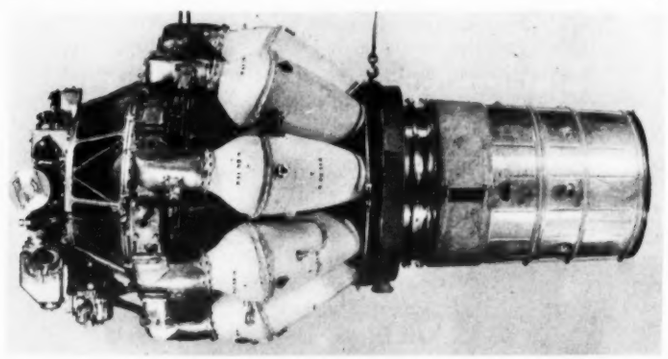
Maintenance is an all-embracing term, and in order to present a clear picture it is necessary to divide it up into several classifications. There is the *between-flights and daily work*, which is mainly inspection from the outside without removing cowlings, engine running and functional checks of moving parts and controls; then there are the *periodic servicings* (at between 50 and 250 hours), in which detailed inspection and rectification is done after removal of cowlings and parts of the engine; and, finally, there is the *overhaul*, in which the engine is stripped completely and entirely renovated.

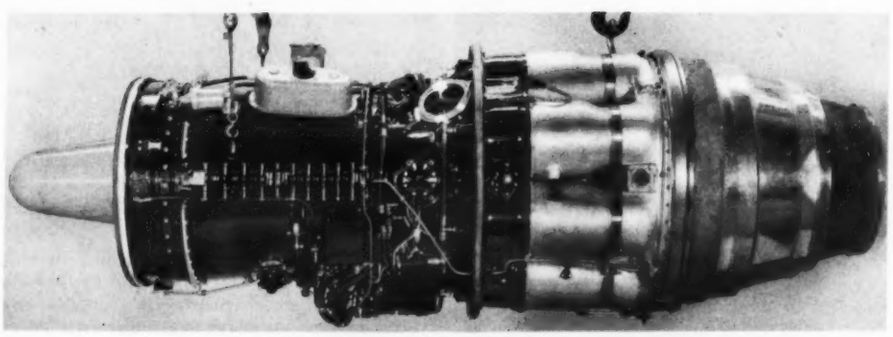
The jet engine has immediate and obvious advantages over the piston type because it is essentially simpler, has fewer moving parts and has no ignition system. Furthermore, because there are no reciprocating parts, vibration is virtually eliminated, so that wear and tear on engine and airframe are greatly reduced. Against these virtues have to be weighed the troubles arising from high temperatures and high r.p.m.

Daily Inspections

The daily inspection of a jet engine is a simple job. It is given a look over to see that there are no signs of leaks from the fuel and oil systems. The latter is, incidentally, particularly simple since it will be contained in the engine itself if it is a centrifugal, or it will consist of a small tank and cooler mounted on the engine if it is an axial. There is no propeller and no constant-speed unit which could form sources of leakage, no large tank and cooler or intricate piping as in the piston engine. The impeller has to be examined for damage caused by stones; this is easier to see with a centrifugal, which is also less fragile than an axial. The turbine blades are examined by shining a torch into the jet pipe. The jet pipe itself, which expands considerably at working temperature, is mounted on a swivel, and this is examined carefully, as it can cause a deal of trouble if misaligned. The engine run-up is a matter of watching and recording oil temperature and pressure, burner fuel pressure, jet pipe temperature, and the r.p.m. at the idling, cruising and take-off throttle positions. During the run a mechanic on the ground listens carefully for scraping or groaning sounds that would indicate turbine or bearing failures.

This daily inspection gives an indication of the sources of trouble, and therefore the maintenance needs, of the jet turbine. The engine is essentially simple and has only the one major moving part, the shaft on which compressor and turbine are mounted. This shaft is better off than the crankshaft of a piston engine, since it has no fluctuating loads other than simple acceleration to and deceleration from working r.p.m. The high rotation speeds—varying from about 6,000 to 20,000 r.p.m. according to type—bring mechanical difficulties in the design of shaft bearings, which have to have very close manufacturing tolerances on the very small clearances, careful lubrication and cooling. In particular, the rear bearing, exposed to conducted heat from the turbine, has been a source of unreliability in the past. Being at the very heart of the engine there is little that can be done to help it during routine maintenance.



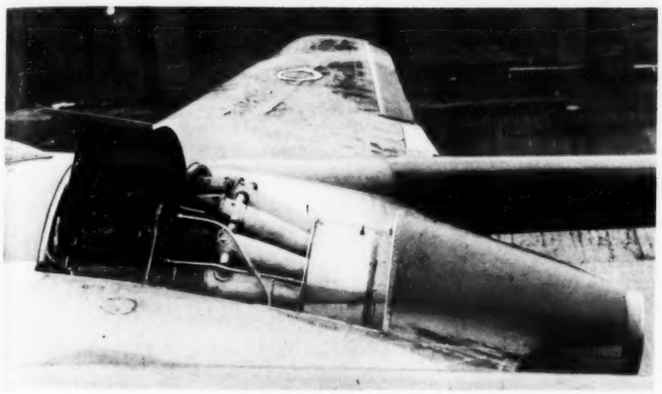


Essential simplicity of the jet engine is clear from these pictures of two leading British military engines : the Rolls-Royce "Nene" centrifugal and "Avon" axial types.

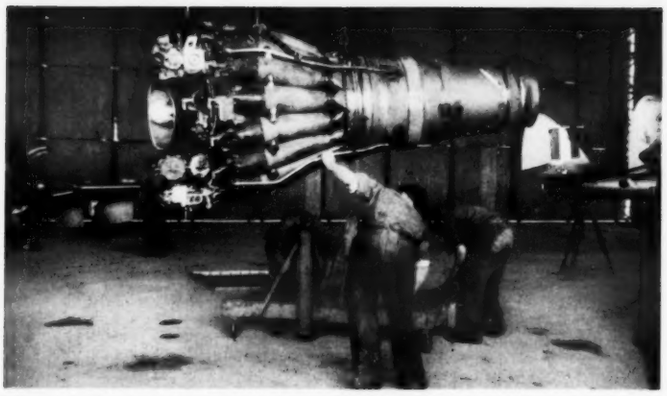
The Points to Watch

While the engine is in the airframe the only servicing possible on the impeller is visual inspection and listening for sounds of fouling. The centrifugal impeller with an anodised light-alloy rotor can be damaged by quite small stones, but continues to be serviceable even when chipped, while if it has a steel leading edge it is virtually indestructible. The blades of an axial compressor are more vulnerable and their delicate profiles are subject to loss of efficiency through abrasion.

At the other end of the shaft is the turbine disc and its blades, made of different nickel alloys. These are the parts that have to stand the strain of working at high tempera-



The "Goblin" engine of the de Havilland "Vampire" and its accessories are easily reached from the ground or the wing through large access doors and panels.



Sling, tackle and stand for the de Havilland "Goblin" are simple because of the light weight of the centrifugal jet engine.

tures, and they are naturally the most vulnerable components of the engine. The greatest problem here is creep, both the disc and the blades "grow" through the combined effects of centrifugal force and heat. A blade that has grown only a couple of hundredths of an inch in length will have a marked "waist" in it—like a tensile test specimen. Frequent checks are made for blade growth and, in order to guard against loss of concentricity, this is done by measuring the gap between the blade tips and the turbine shroud ring on diametrically opposed pairs of blades. When the engine is in the airframe, one of the more slender mechanics is pushed head first along the jet pipe with a torch and feelers in his hands. The job only takes a few minutes in this way, although in the early days removal of the tail pipe was necessary. With the introduction of afterburning (re-heat) such a direct inspection will be impossible because of the fuel nozzles in the tail pipe.

The flame tubes, consisting of inner and outer "cans," do not give much trouble today, although sometimes they chafe round their edges at the hot turbine end. Like all these hot-running parts, they have to be freely mounted to allow for expansion and this is always a possible source of trouble. The burners, or fuel injection nozzles themselves, are subject to "coking"—the same heavy carbon encrustations that are familiar to anyone who has used an oil stove. Upon the efficient functioning of these jets depends the power and fuel consumption of the engine, so they must be easy to clean. The burners are, therefore, made so that they can be withdrawn forward through the compressor casing for cleaning. They can then be dismantled, re-assembled in a jig, and replaced—the whole job requiring a reasonable degree of fitting skill.

Since clogging of the burners is a serious defect, it follows that the filtering of the fuel system is vital. Fuel is pumped from the tank to the engine and then stepped-up to high pressure for delivery to the burners. Filters at each pump require periodic cleaning. It is also important that the bulk fuel supply, *i.e.* in the tankers, is very carefully filtered.

Accessories are similar to those for piston engines save for the barostat, an altitude-compensating device that automatically adjusts the fuel supply for throttle opening and height. Although a precision instrument, this unit gives little trouble and does not require much servicing.

Periodic Servicing

Such are the principal servicing requirements of the jet turbine, to be carried out in the aeroplane, or with the engine removed. The engine is taken out at some set time —100 hours, or even 250 hours— and the jet pipe and tail cone are removed, together with two or three sample flame tubes. If the inspection is satisfactory, the parts will

On the Gloster "Meteor" general engine servicing is carried out through readily-detachable panels between the wing spars. The greater part of the engine itself can receive attention as shown. *(Crown Copyright.)*

The accessory gearbox for the "Meteor" is in front of the spar and removal of the nose, cowling and a short length of leading edge, made in one piece, makes all items accessible. This photo, showing the airwoman *kneeling* to work on the spar, emphasises the low "sit" of jet aeroplanes. *(Crown copyright.)*

Tail fuselage removal for engine access on the Lockheed "Shooting Star."

Engine removal by sliding rearward is the system adopted on the twin-engined McDonnell "Banshee." The combination of lateral and vertical movement is always rather more tricky than the simple up or down hoist.

then be replaced, the remaining minor work done and the engine returned to its airframe —all in a matter of a working day, or thereabouts. Removal for a major overhaul, complete strip, by the makers or at a fully-equipped base, is done at about 500 hours on most British jets—while 1,000 hours is within sight.

So much for direct maintenance of jet turbines. It is a simple engine and its maintenance is simple; only the material stresses due to the high working temperatures cause complications and shorten "life." It was lack of suitable materials that delayed the making of the first gas turbines, so there is nothing new in the problem, and research goes on continually to improve the metals.

Installation Difficulties

Simple though the jet turbine engine is, its installation is often not so. For best aerodynamic results the engine is buried in fuselage or wing and, even though routine maintenance is light, it can easily be complicated by inaccessibility. The short undercarriages of most jet aeroplanes usually make it easy to reach the engine from the ground with the minimum of ladders and trestles, but for removal large panels have to be taken off. British practice, so far, has favoured lifting the engine up out of the fuselage, while in America a detachable rear fuselage and tail are popular. While the former is clumsy and requires a crane, the latter means the use of a special wheeled dolly as well to adjust the rear fuselage up to the main part. A jet engine is very simply mounted, with few connections, but the buried installation can waste a great deal of time, despite claims to the contrary.

The light weight of the jet engine and its usual three-point suspension mean that the simplest of engine stands will hold it. Not only does this ease the provisioning of the ground accessories—for most stands could easily be made up on the spot—but it also means that the engines are very accessible when mounted on them. Lifting tackle, too, need not be as robust as that required for high-powered piston engines. These facts have done much to influence designers of British single-engined fighters—the Vickers Supermarine "Attacker," 510 and 535 and the Hawker "Sea Hawk," P-1052 and P-1081 —to adopt the practice of removing the engine upward, so avoiding the uncoupling of flying controls necessary with tail removal. It may well be, however, that the demands of increased performance may change this policy.

In the English Electric "Canberra" accessibility has been achieved, at some aerodynamic cost, by mounting ahead of the spar. The pod mounting is another solution, which must be the best of all for maintenance, but its aerodynamic qualities are the subject of fierce dispute. The inter-spar position is reasonably accessible on the Gloster "Meteor," although no one would call it ideal; but on the de Havilland "Comet" it is nearly so. The engines are slung on three-point mountings and are laid bare when the quick-release doors below are opened. Removal is by strop through an access panel in the top of the wing exactly over the C. G. Fuselage bulges and near-fuselage bulges, as in the Northrop F-89 "Scorpion" and Avro-Canada CF-100 "Canuck," are reasonably accessible installations for maintenance—but their aerodynamic qualities are unknown quantities to most people.

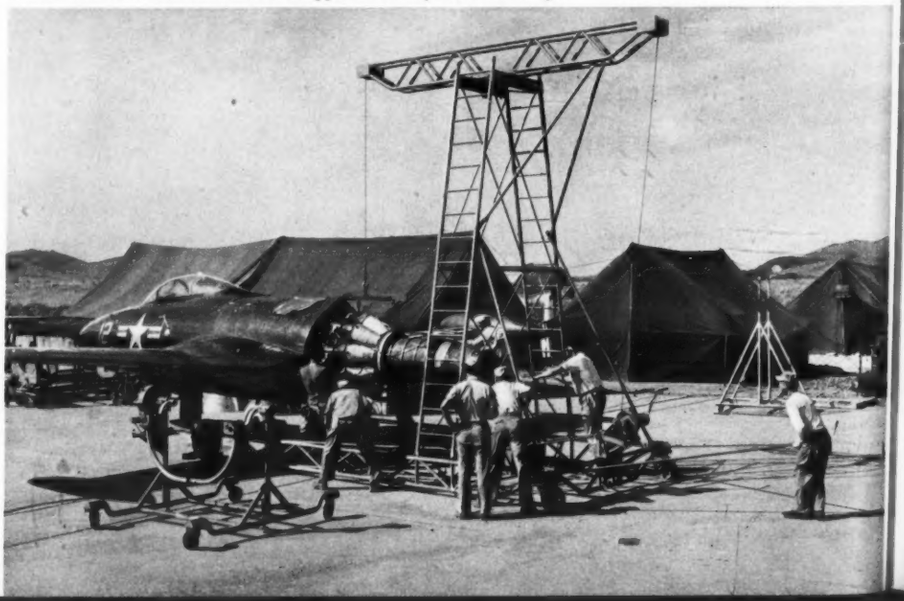
Accessibility, then, is a major headache in jet maintenance, but designers are alive to its importance and are trying all possible methods.

Ground Equipment

The starting of jet engines is a servicing problem of considerable magnitude. With the centrifugal impeller, rotor air resistance is not too great and the engine can be turned by an electric starter—albeit the loading is rather long. Aircraft batteries may be used in emergency, but it does not do them much good, as can be imagined when it is realised that about *double* the number of ground batteries are required for a jet as compared with a piston fighter squadron.

The axial engine is more difficult. The Germans used small motors mounted in the nose of the engine. Compressed air is also used for some types which means very cumbersome ground trolleys stacked with cylinders, and extensive charging facilities. The latest development, the gas-cartridge starter, looks a very promising device. Small in itself, it has the advantage that it is self-contained on the aeroplane, requiring only a supply of cartridges. In this respect,

A typical scene when changing an engine by rear fuselage removal. The Grumman F9F-2 "Panther" airframe balances steadily on its tricycle landing gear, and the engine can be lifted by whatever crane is available—the US Navy type shown is much more complicated than any that would be used by the RAF. On the left is the engine stand. This view does not show the support necessary for the fuselage.



it may well become universal for jet aeroplanes, as it has with Naval aircraft, where battery trolleys are very inconvenient.

To sum up, then: the jet engine is simple to maintain, mainly because of its few moving parts and the absence of reciprocating components. Adjustments are few and fairly easy to carry out. "Repair by replacement," rather than reconditioning, is the rule, and that mainly affects the hottest parts—turbine and nozzle guide vanes. Accessibility can be a problem with streamlined installations, but is one that is being tackled ingeniously. Ground equipment just about breaks even, though even here the tendency is toward simplification.

The jet engine has had an airborne life of about ten years, a practical one of five. Remember what piston aero-engines were like for reliability and maintenance in 1920 —and the jet wins hands down.

Servicing Grumman "Panthers." The machine in the foreground is awaiting engine removal and the tail has already been taken off. The engine stand is waiting in the foreground. The forward-sliding nose cowling is an interesting innovation for access to the nose-mounted armament. Behind the nose are a series of trolleys for supporting the tail fuselage when it is removed for engine servicing. It is noticeable that a large part of the "Panther's" wing root fairing is built integrally with the rear fuselage and comes away with it.

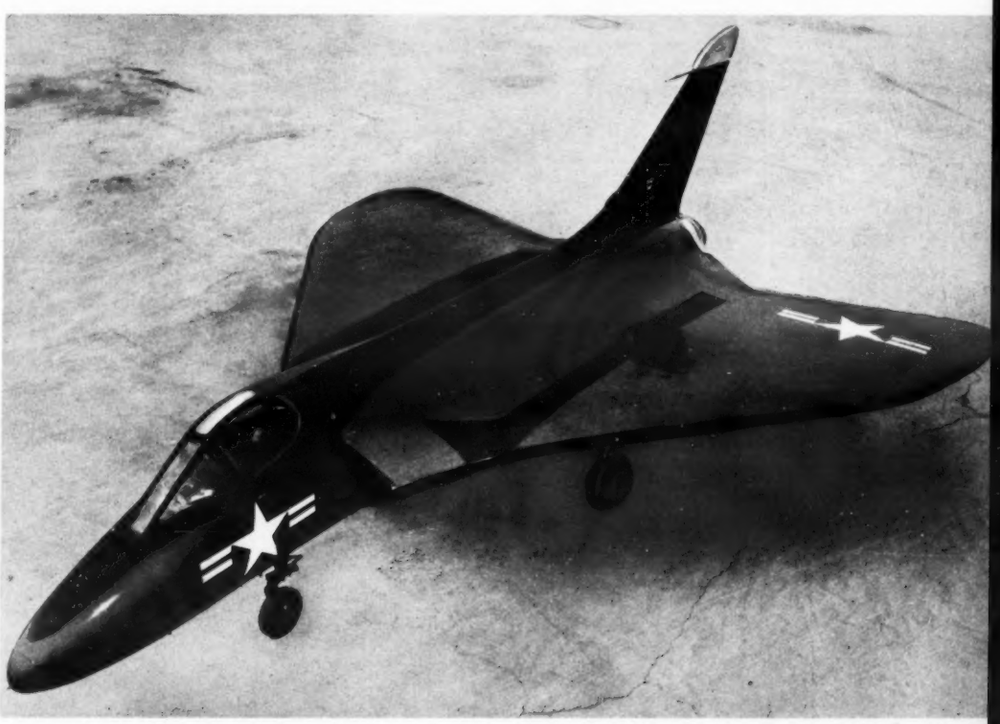
Stop Press *Jet*

The statement that our list of jet fighters (cf. elsewhere in this issue) might have become incomplete by the time it appears in print is only too true: on January 29th Douglas Aircraft Co. in Santa Monica, Calif., issued a first picture of its new, supersonic naval fighter prototype, the *Douglas XF4D*, together with the announcement that the aircraft had successfully flown for the first time at Edwards Air Force Base, Muroc Dry Lake, California.

Designed to be catapulted from carrier decks and climb to the upper atmosphere, the aircraft was planned to meet the need for a machine capable of intercepting an enemy on short notice. The type is an addition to the growing family of "delta-wing" aircraft and consists of a triangular plan-form wing with a slim nose extending forward to provide a cockpit for the pilot. It was veteran Douglas test pilot Larry Peyton who flew the aircraft on its maiden flight at the Californian desert base.

The Navy has no immediate production plans for the new aircraft, despite its unusual performance. The type was ordered for a flight test programme of the delta-wing plan-form established in conjunction with the US Air Force, the Convair F-92A being the USAF counterpart. The XF4D is powered by a Westinghouse J-40 turbojet producing 7,500 lbs. of thrust and *nearly 11,000 lbs.* with afterburning. Capable of supersonic performance in steady level flight, it is noted chiefly for its astonishing rate of climb of 15,000 feet per minute at sea level. Its endurance, however, is only 25 minutes deck-to-deck. It weighs 16,000 lbs. gross, and its wing plan-form is reminiscent of the Lippish P.13 design of the World War II era, which was never built.

The Navy is now waiting for the Grumman XF10F fighter (which together with the XF4D was mentioned in *Interavia Air Letter* for the first time in the latter part of 1949), yet another secret jet fighter designed for pure interception duties. The Grumman fighter has a variable-sweep wing and is expected to answer many of the US Navy Bureau of Aeronautics' problems of high-speed aircraft operating aboard carriers.



1951 Aviation Prospects

Nobody knows what 1951 is going to produce—war, peace or continued non-belligerence by mutual consent? What will be the effects of this instability on aeronautics in the major air-faring countries? These were questions which we asked ourselves at the beginning of the year.

We wrote to our correspondents and friends in the major capital cities and asked them to write us brief summaries of how they, as the men on the spot, judged the prospects of military and civil aviation and of the aircraft industries in their territories.

This month we publish a first instalment of their replies. Altogether these reports seem to indicate that the world's aviation people are looking to the future with confidence. Not only the aircraft factories —busy with defence orders—are anticipating a period of stability. The commercial airlines, who can develop freely only in times of peace, are all expecting to do more and better business during 1951 than in the record-breaking year of 1950. This year therefore seems to herald much intensified operations for commercial air transportation, full employment for the manufacturing industry, and a vast expansion for the military air services. How the taxpayer is going to foot the bill for the thousands of new military aircraft now being produced and the large air forces being built up is an unsolved problem, of course...

ED.

USA

Washington, January.—This year will assuredly be the biggest peacetime year in the history of US aviation, largest since the fabulous achievements of 1944, yet it will be only the first step in a rapidly-accelerating three-year expansion program. Aircraft production will be more than twice that of 1950, airline travel should rise slightly—possibly by five percent—and only the production and use of personal-type aircraft will drop.

Military Aircraft

Military aircraft production expansion has actually been under way a full year and to form a basis of comparison it should be noted that the industry produced about $1,500,000,000 worth of aircraft in 1949 and about $2,000,000,000 in 1950. During 1951 the industry will deliver between $5,000,000,000 and $6,000,000,000 worth of military aircraft against current orders in excess of $10,000,000,000.

President Truman announced a five-fold increase in aircraft production in his speech declaring a state of national emergency last December, but it later appears that his advisers garbled the facts and that this expansion is planned over a two-year period instead of one. The industry will produce about 8,000 military aircraft during 1951 and 15–18,000 during 1952. In this expansion process, however, great attention is being paid to the creation of productive capacity beyond current orders and President Truman has asked for an industry capacity of 50,000 military airplanes a year (the same quantity asked by President Roosevelt in May, 1940), although actual production will run less than half this under the present program. The US does not intend to get caught short in its aircraft production capacity as it did in World War II.

The total of $10,337,242,000 worth of military aircraft currently on order includes $6,603,440,000 for the Air Force, $2,542,922,000 for Naval Aviation, $42,376,000 for the Army Ground Forces and $1,148,504,000 for aircraft to be sent abroad under the Mutual Defense Assistance Program. The President's budget for the 1952 fiscal year, which begins next July 1st, contained no detailed breakdown of military expenditures, other than a request for $101,000,000,000 total. If this budget follows the current ratio of procurement, it will call for the production of $20,000,000,000 worth of military aircraft during the 1952 fiscal year, which is, of course, quite beyond the capacity of the industry including its current expansion program.

A number of military aircraft stand out already in this program. The most important of these is the Boeing B-47 "Stratojet" bomber, which will involve the greatest single production program in the entire industry. Douglas and Lockheed aircraft companies have contracted for production of the jet bomber and dozens of companies are already participating in the Boeing production program as sub-assembly suppliers. The current production model uses six General Electric J47 turbojet engines of 5200 lb. thrust each but a new model will be powered by four Allison J 35–A–23 engines developing about 10,000 lb. thrust each, or more than the six engines they will replace. This model will be capable of supersonic speed and the current models attain sonic speed in shallow dives, making it one of the outstanding aircraft in modern design history.

Among the fighters the new Republic F–84F "Thunderjet" appears to figure most prominently. Soon to be equipped with the Wright-built Armstrong-Siddeley "Sapphire" turbojet engine of 7200 lb. thrust, vast quantity production of the airplane has been ordered by Republic and the fabulous General Motors Corp., which will build it in a Kansas City, Kansas, plant. Navy carrier-fighter plans revolve around the Grumman F9F "Panther" for use in the next two years, but the long range plan is banking heavily on the still-secret Grumman XF10F fighter, which features variable-sweep wings and supersonic performance.

More familiar types in the expanded program are the venerable Convair B–36 bomber, a turboprop-powered version of which is now being studied in competition with the turboprop Boeing B–52. Meanwhile, the combination jet and piston-engined B–36D will be continued in production at an increased delivery rate. Douglas' new A2D "Skyshark" turboprop-powered attack plane is being ordered in large quantities as is the Douglas F3D–3 "Skyknight" all-weather carrier fighter powered by two Westinghouse J40 engines of more than 10,000 lb. thrust with afterburning.

Lockheed will expand production on its F–94 series of all-weather fighters, including the new thin-winged F–94C with 8,000–lb. Pratt & Whitney J48 afterburner-equipped jet engine (licence-built Rolls-Royce "Tay"). North American will increase its F–86D and E "Sabre" production enormously and the Navy has ordered its turboprop-powered A2J carrier bomber into production.

The familiar Boeing C–97 "Stratocruiser" will carry the brunt of long-range, high-speed air support duties while the huge Douglas C–124 (a new version of which, powered by four Pratt & Whitney T34 turboprop engines has been ordered) will handle the heavy, bulky freight loads over shorter distances.

The Army's procurement is for liaison aircraft, chiefly the Cessna L–19 plus the winner of the new competition recently concluded for larger light transports, in which the de Havilland "Beaver" figures prominently.

Washington : The Capitol.

Airlines

Even without war, the airlines are certain to undergo substantial interruptions of normal traffic flow during the year by emergency war-important shipments of men and materials. However, large numbers of twin and four-engined transports will go into service during the year and the increased capacity is certain to accommodate expanded traffic. Best estimates are for a five percent increase over the record-breaking performance of 1950. US scheduled airlines now operate 1,215 transport aircraft but have an additional 173 on order, most of which will be delivered during the year following the issuance of Defense Priority Orders for their

completion as essential production. The airlines now serve 977 cities over 335,000 miles of airways, flying 16 million passengers. Total capital investment of the US airline industry is currently about $360 million.

Rapid expansion of electronic aids during the year will greatly enhance the strategic value of the airlines to the military, who will control most of the airways during the year. Completion of 300 Omni-range stations in the US during the year will complete the changeover to VHF communications throughout. More than 100 Distance Measuring Equipment stations will be in operation, thereby making off-airways flying a regular operational practice. Additionally, Airport Surveillance Radars will be installed in increasing numbers and by the end of the year virtually all-weather operations will be possible, thereby increasing schedule reliability to about 99 percent with accompanying increases in revenue plane-miles.

Personal Aircraft

Little but pessimism prevails in this industry, many leading companies of which have already announced cessation of production in favor of subcontracting work for the military airframe companies. Oddly enough, the steady decline in production (in which production has been about halved each year since the 34,568-place record of 1946) was reversed during 1950 when a slight gain was made. However, since 1948 the trend has been strongly towards the four-place business airplane rather that the two and four-place pleasure model, thus rapidly taking the plane away from the "personal" category. Production should drop to a new low during the year and by 1952 only military liaison models will be in production.

Great Britain

Aircraft Industry

London, January.—The events of 1950 have done much to stabilize all aeronautical activities in Great Britain—for good *and* evil. Since the end of the War affairs had been becoming increasingly unsettled until, in the early part of last year, the Government's economy measures with the Armed Forces brought things to their lowest level. Then, in the summer the increased tension throughout the World led to the announcement of the £3,000,000,000 arms programme. Sad as was this necessity, it is one that should have been both realised and faced by the nation's rulers long before but undoubtedly they were concerned far more with internal politics than with international statesmanship.

For the rest of the year the change in armament policy was little felt within the Industry, but there was a gradual increase in the confidence that had been markedly lacking before. Because of this, the British Aircraft Industry enters 1951 in a healthy state of mind—although in body, as represented by trained manpower, it is much weaker. Production is going ahead on military types: fighters, trainers, reconnaissance aircraft—and *one* bomber. This work will absorb much of the Industry's resources, but emphasizes the lack of new heavy and

London : Tower Bridge.

long-range bombers for which, even should prototypes appear in 1951, the manpower and factory space would scarcely be available before 1953.

Behind these military orders lies the backing of the aero-engine industry, which is being expanded in the turbine field. Until now, Britain has concentrated on the centrifugal unit, but large resources are now being diverted to manufacture the axial Rolls-Royce "Avon." Whatever the relative merits of the two types, there is no doubt that this new policy, with the need for millions of accurately profiled compressor blades, will throw a heavy load on the country's precision machining capacity. Fortunately, the machine tools are there, because that field has continued to develop steadily since the first re-armament programme in 1937—at the beginning of which it was lamentably inadequate.

Without radio, radar and instruments, airframes and engines are useless and here, too, there should be ample reserve. Both government and private research has gone ahead steadily since the end of the War and British equipment is technically excellent. In peacetime, the specialised aeronautical equipment is more a matter of prestige than profit to the manufacturers, but the civil manufacturing potential is there for application to rearmament.

Service Aviation

Military aeronautics—the Royal Air Force and Naval Aviation—is due for expansion and is concentrating on increasing trained manpower. The RAF in particular is very concerned with the problem and they are setting about making good the shortage in three main ways: increasing training facilities for air crew and technical personnel; improving pay and prospects for full time entrants and also making the maximum use of conscripts, including commissioning the best of them; making the greatest use of the men available by reducing maintenance manhours. The Navy policy is to accept as small a percentage as possible of conscripted, short-time men and to develop a small highly-trained regular and reserve body.

J. H. S.

Air Transportation

London, January. — The current year will mark the advent of a new era in British civil aviation with the introduction, on commercial routes, of the de Havilland "Comet" jet airliner. The second prototype is due to be delivered to British Overseas Airways Corporation in February and will be used for crew training and proving flights. One or two production "Comets" for scheduled services are to follow later in the year and, according to BOAC plans, will be introduced on the London-Rome-Cairo service. Progressively, the type will then be brought into service on the long distance routes to Australia and South Africa.

British European Airways also will be introducing one of its two new airliner types now on order. Delivery of the first "Elizabethan" is expected during the summer. "Elizabethan" is the BEA class name given the twin-engined Airspeed "Ambassador." Designed for the shorter, high density Continental routes, the "Elizabethans" will carry up to 49 passengers. A number of these aircraft should be operating on scheduled routes by the end of 1951. Delivery of the Vickers "Viscount" turbo-jet airliner, to be known as the "Discovery" class with BEA, is not expected until 1952.

As for the commercial prospects of Britain's two State-owned Airways Corporations for the current year, these are necessarily contingent on the overall world situation. The year 1950 was by far the best year the British airlines have had. Up to the end of November 1950, BEA, for instance, had made a net profit of £4,742 for the first eight months of the fiscal year 1950/51, as against a loss of £403,978 for the same period a year before. BOAC, too, enjoyed very substantial traffic increases and in September made its first net profit. Preliminary figures for January 1951 show a substantial increase over 1950, the West African route and the New York-Nassau "Stratocruiser" service proving particularly successful. Peter Masefield, Chief Executive of BEA, writing in the Corporation's Magazine, says that with the Festival of Britain as an added salesman, BEA should reach its target of increasing traffic by another 25% after a hard struggle.

Interline bookings record a drop in American advance reservations for the summer season. This is directly traceable to anxiety over the possibilities of war. But if some *modus vivendi* is arrived at between the Western and the Eastern powers, the situation may improve immediately and substantially.

It should also be pointed out that, uncertain as American traffic prospects may be at the time of writing, BOAC will benefit from the healthy growth in Commonwealth travel, while BEA's traffic figures will be favourably affected by the increasing exchange of visitors between the United Kingdom and European countries. Although the number of Britons able to afford more than £50 each for foreign travel is limited, the recently increased foreign travel allowance of £100 per adult per annum is bound to have some effect on BEA's Continental services figures.

Summing up, it is correct to say that the British Airways Corporations' traffic figures, both passengers and freight, are still showing an upward trend and, given reasonably normal conditions, BOAC and BEA should in 1951 continue to improve their financial

results. Like all other airlines they will suffer some uncertainty until the world situation is stabilised and their progress will be somewhat retarded by increasing operating costs. *Paul Lieven.*

Sporting Aviation

The operation of personal aircraft, by individuals or by clubs, is a gloomy prospect. Costs that have been steadily rising have been crowned by the petrol tax and only the wealthy can fly nowadays. One result of this is that, in the country which put the light aeroplane movement on a practical basis with the D.H. "Moth," there are now no new types in this field. — *J. H. S.*

France

Paris, January.—For the first time since 1947, the year in which the reorganization of the French aircraft industry was initiated, the latter is looking to the future with a certain amount of confidence. The international situation and the necessity of building up the country's defences have persuaded Parliament to adopt the "Five Year Plan" proposed by André Maroselli, Secretary of State for Air at the Ministry of Defence.

However, in spite of the financial allocations voted, the factories are not producing at full capacity. The Five Year Plan came into force only at the end of July, and the greater part of the contracts was therefore awarded only some time after that date. Hence, 1951 aircraft production will not be very extensive, but the Plan at least enabled the aircraft concerns to establish manufacturing schedules which will guarantee them some degree of stability for a certain time.

Aircraft Procurement

The programme established under the Plan comprises *four categories of aircraft:* jet-propelled interceptors, medium cargo aircraft, twin-engined light transports, and trainers.

(a) The *interceptor fighter* programme concentrates on two types of aircraft: the de Havilland "Vampire," built under licence by SNCA du Sud-Est, and the Dassault MD 450 "Ouragan" and its developments. Both types are powered by a Rolls-Royce "Nene" jet manufactured under licence by Société Hispano Suiza.

Even prior to the adoption of the Five Year Plan, 224 "Vampires" and 12 pre-production "Ouragans" had been ordered. A second contract for 210 "Vampires" is now being put into production, whereas of the "Ouragan" a pre-production series of 22 and a first production batch of 150 have so far been taken in hand. The latter order will be supplemented shortly by a second contract for 150 to 200 aircraft of the same type. Subsequent orders will call for developments of the "Ouragan," for example the MD 452 "Mystère," an aircraft featuring thin wings and powered either by the Rolls-Royce "Tay" or the ATAR 101. The production rate of the MD 450 "Ouragan" —which has been approved as an interceptor by the Inter-Allied Committee of Experts— is reaching 40 aircraft a month.

Nothing has so far been disclosed about any contracts awarded for future military prototypes, but indications are that SNCA du Sud-Est, SNCA du Sud-Ouest, Marcel Dassault and René Leduc are engaged in the development of supersonic interceptors.

As regards foreign equipment, France is expected to receive a number of Republic F-84 "Thunderjet" fighters before the end of March. By the end of 1951 the French Air Force would thus include 11 groups (equivalent to USAF groups) of "Vampires" and five groups of "Thunderjets."

It is not yet known whether the *Naval Air Service* will order its carrier-borne aircraft from the French aircraft industry or whether it will buy them abroad. In the former case the Navy would have to choose between the Nord 2200, the Arsenal VG 90 and the Bréguet 960.

A number of Nord 1400 "Noroit" amphibians have been ordered. It is likely that, like the Air Force, the naval air service will also take delivery of some Nord 2500 "Noratlas" transports.

Finally, the Navy has shown some interest in the Bréguet 764—developed from the well-known "Deux Ponts" transport—for use in anti-submarine warfare.

(b) *Medium cargo aircraft:* comparative tests between the Nord 2500 "Noratlas" and the Bréguet 890 were completed recently. The winner of the competition was the Nord 2500, powered by two Bristol "Hercules" engines, for which a contract has been placed. A total of 160 aircraft of the type are on order from SNCA du Nord, but a large portion of the work has been subcontracted to Bréguet. The first production aircraft will not be delivered before the second half of 1952.

(c) *Light transport aircraft:* the type selected is the Dassault MD 315, of which 295 machines were ordered before the adoption of the Plan, at the end of 1947. Production is in full swing and deliveries are rapid. Several Air Force groups in North Africa are already equipped with them.

(d) *Trainers:* 100 SIPA 111 and 112 aircraft were ordered prior to the adoption of the law. Furthermore, a pre-production series of 15 Morane MS 732 trainers was started last year.

As in the past, Hispano-Suiza and SNECMA will provide most of the engines for these military aircraft. Hispano-Suiza, who are manufacturing Rolls-Royce "Nene," have also acquired the "Tay" licence rights and will start production of this type in the near future.

SNECMA has received a production contract for the ATAR 101 jet engine, the static thrust of which is expected to exceed 6,600 lbs. some time in the near future. It has acquired the manufacturing rights to the Bristol "Hercules" engine and is continuing the manufacture of its own "Super-Mars 12 S" and "4 LO" types.

So far as Societé des Moteurs Potez is concerned, this Company has received a first production contract for its 240 h.p. Potez 6 D six-cylinder engine.

Finally, Turboméca is continuing with the development of its small jets, the "Piméné," "Aspin," etc.

Air Force Personnel Strength

The personnel strength of the French Air Force will reach 91,000 in 1951. The establishment of officers and N.C.O.s— 5,200 and 27,000 respectively—has been increased considerably.

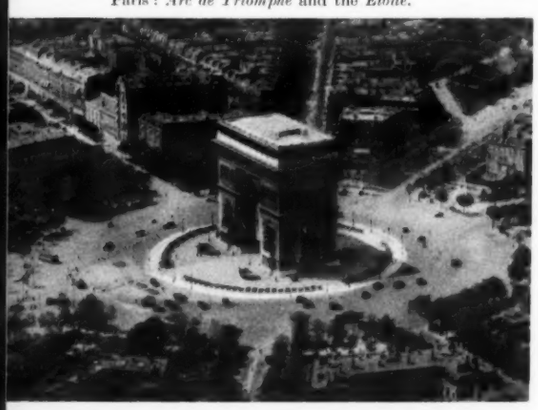
An "Active Reserve" (week-end pilots) has been established and the "Génie de l'Air" (engineering service) has been resurrected.

Air Transportation

In 1951 the bills governing flying personnel and private airlines will be voted. Thanks to the *Association du Transport Aérien Français* (ATAF), whose President is René Briend, Deputy Director-General of Air France, the activities of the private companies have been harmonized with those of Air France. Grouped within ATAF are all the major air transport companies, with the exception of Aigle Azur, which will join in the near future.

Air France, which has continuously intensified its operations since the end of the war, is expected to achieve even better results during 1951, thanks to the inauguration of new services and the acquisition of new flying equipment, as well as to the company's efforts to "popularize" air transportation by the introduction of cheaper fares—off-season, off-peak tickets, excursion tickets, group fares, tourist-class tickets, etc. Air

Paris : *Arc de Triomphe* and the *Etoile.*



France's air fleet now consists of 19 Lockheed L–749 "Constellations" (4 new aircraft of the type are due to be delivered in 1951), 28 Douglas DC–4s, 31 "Languedoc 161" aircraft which will be converted to carry 45 instead of 33 passengers on coach services, and 33 Douglas DC-3s.

The nine active private companies, most of which run services between Metropolitan France and her overseas possessions, at present have a combined fleet of 72 aircraft, including 3 SO 30 P "Bretagnes," 10 Douglas DC–4s, 50 DC–3s, 4 Curtiss C–46 "Commandos," 4 Bristol 170s and 1 Miles "Aerovan."

Most of the private carriers are backed by shipping lines. Their biggest problem is the renewal of their air fleets.

French types available to them, apart from the SE 2010 "Armagnac" now being manufactured for Air France (TAI is reported to be interested in the same type), are the Bréguet 761 "Deux Ponts," the twin-engined SO30P "Bretagne" (of which Air Algérie has bought three), and the Nord 2501, cargo version of the Nord 2500 high-density passenger transport.

As regards the top administration of French commercial aviation, a rumour now circulating in Paris mentions the possible creation of a Division of Commercial Aviation under the Department of the Secretary General of Civil and Commercial Aviation which, as is known, has no political character.

Lightplane and Private Flying

The high cost of aircraft and... the fear of drawing the attention of the tax collector have persuaded many private pilots to abandon their favourite sport.

A few dozen light aircraft (Brochet MB 70, Jodel, Chapeau JC1, Minicab) have been ordered by the Division of Light and Sporting Flying. These two seaters will be used for the training of young pilots by the aeroclubs.

Italy

Military Aircraft Procurement

Rome, January.—Italy will spend about 110,000,000,000 lire on her air force and civil aviation in 1951. This figure includes the ordinary air defence vote and the supplementary rearmament appropriation which, though it is to be spread over three years, can be allocated in 1951.

The aircraft procurement programme calls for 150 de Havilland "Vampire" fighters, including 70 imported from Britain and 80 built under licence by Fiat and Aeronautica Macchi; 200 Fokker S.11 trainers built under licence by Aeronautica Macchi and Industrie Meccaniche Meridionali; about 100 trainers of a model derived from the North American AT-6; 30 Fiat G.59 trainers powered with Rolls-Royce "Merlin" engines; as well as a few dozen Fiat G.46 and Ambrosini S.7 trainers and Piaggio 136 amphibians. Deliveries, which will be supplemented by American aircraft under the Military Aid Programme, will be extended over a lengthy period of time in order to keep the strength of the Air Force within the Peace Treaty limit of 200 combat aircraft and 150 military trainers and transports.

Italy's aircraft industry is now developing jet-propelled trainer aircraft, including the Fiat G.80, which is in an advanced stage of construction,—and the Macchi B.324, which is still in the design stage. Finally, Ambrosini is developing a swept-wing jet fighter.

The engine divisions of Fiat and Alfa Romeo have initiated production of the de Havilland "Ghost" jet engine to power the de Havilland "Venom" fighter, which will succeed the "Vampire" on the production lines towards the end of this year.

Several Italian companies are engaged in the import and the manufacture under licence of radar and other electronics equipment required for the anti-aircraft defences and for navigation aids and air traffic control purposes. About 11,000,000,000 lire has been allocated to the anti-aircraft defence units—spread over three years, like the remainder of military expenditure—for the acquisition of equipment.

Modern aircraft armament will come from the factory of a new combine formed recently by the Italian firms of Breda and Berretta and by Hispano-Suiza, the Swiss automatic cannon manufacturers.

Service Aviation

By the end of June seven first-line groups of the Italian Air Force will be fully equipped on a provisional basis, six of them with North American F–51 "Mustangs" and Republic F–47 "Thunderbolt" piston-engined fighters and one with "Vampire" jets. "Mustangs" and "Thunderbolts" will later be shifted to the training units and replaced with "Vampires" or perhaps Republic F–84E "Thunderjets." Transport and communications duties have been assigned to a group of Beechcraft C–45 "Expediter" light transport and several units operating Fiat G.12 and SIAI M.82 transports.

Training of pilots is limited to 200 a year. About 100 cadets will be enrolled in the regular curricula of the Air Force Academy. An increasing number of technical schools is being brought into operation in order to provide a large reservoir from which the 25,000 men authorized for the Italian Air Force establishment under the Peace Treaty are to be selected. By the end of June, Italy will have about 2,500 trained pilots, not all of whom are on active duty.

One of the major efforts of Italian military aeronautics is concentrated on the rehabilitation of air bases, depots and supply services, in order to provide the small Italian air arm with a maximum degree of mobility and offer extensive facilities to other members of the Atlantic Pact Organization in the event of war.

Rome : The *Castel St. Angelo.*

Air Transportation

Italian civil aviation continues to be governed by the Ministry of Defence. This may be attributed to the fact that in Italy the manufacture of military transport aircraft has not been given a priority in the country's rearmament effort, and the commercial airlines are therefore the only reserve on which the Air Force can draw for its transport needs in an emergency. To maintain this reserve, the Finance Minister has been asked for a subsidy of about 10,000,000,000 lire for commercial aviation, but it is unlikely that this request will be granted. On the other hand, air transportation will benefit from the aerial rearmament through the improvement of airport facilities and navigational aids.

The situation of the commercial airlines is precarious on the whole. The airlines lost about 1,500,000,000 lire in 1950 and, without subsidies or other forms of assistance, are unable to make good these losses. Today the airlines are living from hand to mouth. One of the major domestic air carriers, ALI-Flotte Riunite, whose capital is wholly privately owned, has announced stringent measures of retrenchment.

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To sum up, it is correct to say that from the point of view of morale Italian aeronautics has fully recovered from the débâcle of 1943. Officers and men of the Air Force and members of the industry have regained their confidence, and the country's youth again believes there is a future for them in the air. Rather less optimism is expressed by the airlines and the users of air transportation because of confusion and lack of organization resulting from the non-existence of a national flag carrier and from the clash of opposing aviation interests. These two factors have so far prevented the adoption of a unified national civil aviation policy. *(To be continued.)*

Two Messages to Congress

Breath-taking Production Figures and the American Aircraft Industry

The Voice of America

With the best will in the world it was impossible to say that the Allied cause was prospering. It had taken Hitler's armies barely six months to reach the gates of Moscow. In North Africa Rommel was pressing hard on the British positions and preparing to advance on Egypt. The Atlantic had become a veritable graveyard for shipping. And barely a fortnight earlier the Japanese had decided that their hour had come. One third of the American Pacific fleet lay at the bottom of Pearl Harbour.

In the Oval Study of the White House President Roosevelt read through the text of a message which he was preparing for the forthcoming meeting of the American Congress to three trusted listeners, Hopkins, Beaverbrook and Churchill. Churchill had come to Washington on 22nd December 1941, at the head of a British mission for the "ARCADIA" conference, one of the first secret meetings between the Anglo-Saxon Allies.

The figures cited in Roosevelt's manuscript caused Churchill to send an enthusiastic code message the same evening to the War Cabinet in London... Beaverbrook had been "magnificent" and Hopkins a "godsend." If Churchill credited Roosevelt's adviser Hopkins with the authorship of the figures which so delighted him, he was fundamentally mistaken. Hopkins was not at all happy about the affair and the American War Department remarked: "The President has gone in for the "numbers racket."

What was there in the "State of the Union Message" which Roosevelt presented to the American Congress on 6th January 1942? Nothing more nor less than that US industry was to produce 45,000 aircraft and 720,000 tons of bombs in 1942, not to mention 45,000 tanks, 8,000,000 tons of merchant shipping and 20,000 A/A guns. The programme for 1943 seemed even more astronomic—100,000 aircraft, 75,000 tanks, 35,000 A/A guns, 10,000,000 tons of shipping.

Looking back it is easy to understand the serious doubts felt by the initiated. Roosevelt's forecasts must have seemed quite "irresponsible" when his figure were compared with the production programme for 1942 prepared by US authorities and industry before Pearl Harbour, namely:

28,600 military aircraft,
20,400 tanks,
6,300 A/A guns,
6,000,000 tons of merchant shipping,
84,000 tons of bombs.

It is not without interest that the New York Stock Exchange appears to have shared these doubts. There was no question of a sensational rise in aircraft shares, such as might have been expected following the President's announcement. On the contrary, three months after his message the majority of American aircraft stocks had lost a few points:

	Price at end of 1941 [1]	*Price 27. 3. 42* [2]
Bendix	39 1/2	35
Boeing	19 5/8	17 5/8
Consolidated Aircraft Corp.	20 1/4	20 3/4
Curtiss-Wright	8 1/4	7 1/2
Douglas	66 1/4	63 3/4
Fairchild [3]	8 3/4	1 7/8
Grumman	12 7/8	12 1/4
Lockheed	22	21
Martin	24	22 3/4
North American	12 3/8	11 7/8
United Aircraft	35 3/8	31 5/8

But a little less than two years after Roosevelt's message to Congress Stalin drank a toast at Teheran to the American aircraft industry, "without which this war would have been lost." He had good reason for this toast, for the American aircraft industry had redeemed the President's words.

[1] From "Stock Record." Brown Brothers, Harriman & Co., New York.
[2] From "Daily Market Quotations," Brown Brothers, Harriman & Co.
[3] Curb Exchange.

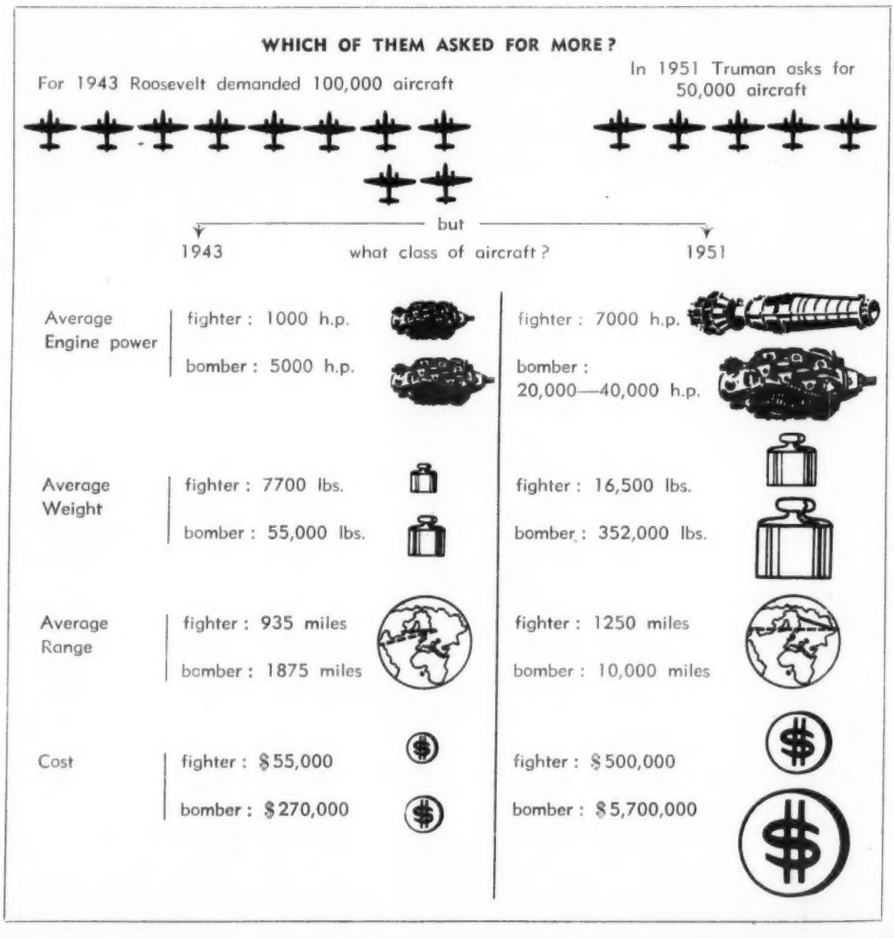
Military aircraft supplied by the American aircraft industry [4]

1940:	6,019
1941:	19,433
1942:	47,826
1943:	85,898
1944:	96,318

Great minds...

Today, nine years later? Once more the USA are faced with the necessity for a prodigious production and financial effort. Although the world crisis has not yet developed into a world conflagration, America must nevertheless hurriedly arm a defence force which, if the worst came to the worst, could withstand the onslaught of half the world. Once more an American President presents his State of the Union Message to the Senate and House of Representatives. In his report on 8th January 1951 Truman speaks of "a big programme and a costly one." He too gives production figures: 50,000 first-line aircraft and 35,000 tanks—but different kinds of aircraft and tanks... It is unlikely that Stalin will now raise his glass to the fulfilment of the Ameri-

[4] From: US Military Aircraft Acceptances 1940-1945, Civil Aeronautics Administration.



can aircraft industry's production programme.

But there are other fundamental differences between Roosevelt's message of 1942 and the one in which Truman has just spurred the American people on to fresh efforts and sacrifices. Roosevelt's figures referred to the output of military aircraft demanded for the years 1942 and 1943. Truman on the other hand speaks only of an increase in industrial capacity which would enable this production target to be attained at a date not yet fixed: "We are not now ordering that many planes or tanks, and we hope that we never have to, but we mean to be able to turn them out if we need them."

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Economic and technical considerations make the attainment of today's target more difficult. The USA are not at war, at any rate not with a major Power. It is therefore not possible to mobilise all the nation's resources for military production. President Truman in fact stressed repeatedly that in spite of the rearmament programme normal peacetime production was on no account to be neglected, but was to be maintained on the broadest possible basis. According to Truman's figures little more than 7% of the national income is at present devoted to the American armed forces for armament purposes. By the end of 1951, however, this figure will have been raised to approximately 18%. But this is still a long way from the 45% of the American budget which was the highest amount spent for military purposes during World War II.

The proportion of the 1951-1952 budget ($140,000,000,000) to be spent on defence has not yet been fixed, much less the total amount to be spent on the whole rearmament programme and the distribution of the credits already granted among the three services. It will probably be some time before the aircraft procurement programme drawn up in the autumn of 1950 can be implemented. Under this programme the USAF was to be increased from 48 groups to 58 by the middle of 1951, to 69 by 1952 and to 90 to 100 by the middle of 1953.

Projected aircraft procurement programme for 1951 to 1954 and later

(in thousand millions)

	1951 [5]	1952	1953	1954	Later years
Air Force	$4.4	$2.5	$1.2	$2.0	$2.8
Naval air arm	2.3	1.8	1.5	1.5	1.5
Total	$6.7	$4.3	$2.7	$3.5	$4.3

*

In addition to this programme the Atlantic Treaty countries are to be supplied with military aircraft to the value of approximately a thousand million dollars during 1951. Some of these aircraft will, however, be taken from existing USAF stocks during the current year, and substantial orders will not be placed with the aircraft industry until 1952.

*

Truman's message also referred to the *greater engineering problems* involved in increasing production capacity. For example the construction of the latest piston-engined bombers with their sensitive and costly high performance engines demands very much more labour, workshop space and equipment than the quantity production of the corresponding piston-engined aircraft of World War II, which today all belong to the medium performance class.

What then of jet aircraft, to which much of this issue is devoted? One jet engine provides roughly the same power as all four engines of a standard bomber of World War II. Present-day speeds necessitate new designs and consequently extensive structural changes (for example the wing skin of a Boeing B-47 is 16 mm thick at its thickest part, or in other words five times as thick as that of the B-17). Stronger materials, such as high-grade aluminium and steel alloys, the complicated equipment for all-weather flight and blind landing, radar equipment for navigation and target identification... It will be clear even to the layman that the facilities for the increase in capacity demanded by Truman cannot be provided overnight. His rearmament plan for 50,000 military aircraft a year seems almost more daring than Roosevelt's wartime plan.

Outlook for the American aircraft industry

With or without the Truman plan it would seem that full employment in the aircraft industry is assured for a good many years to come. Since the outbreak of the Korean hostilities the *backlog of orders* on the books of the majority of companies has trebled, and the Aircraft Industries Association of America estimated at the end of 1950 that *output* in each of the next three years will also treble. The increase in production forecast by the A.I.A. would be sufficient to produce results consistent with the Truman plan figures. In 1946 and 1947 the American aircraft industry produced 1,330 and 2,102 military aircraft respectively. Because of security regulations no figures for production during 1948 and 1949, except for total airframe weights, are available, but the AIA estimated deliveries at 2,200 to 2,400 aircraft (the majority of them probably multi-engined bombers).

The American aircraft industry can therefore look forward with confidence to the immediate future at any rate in the economic field,—except for the little matter of the Excess Profits Tax, an unpleasant surprise sprung on the whole of the American business world at the beginning of 1951. However, President Truman's message to Congress will not have any immediate effect on the value of aircraft shares, since it deals with a relatively long-term policy and does not provide for any immediate increase in orders. The New York Stock Exchange, on which aircraft stocks were already quoted at much higher rates at the end of 1950 than a year earlier, did indeed react to the Congressional message with a fresh rise, but it was only in a few cases (Douglas, Bendix, Bell) that this rise exceeded one point. In the table below are the prices at the end of 1949, the end of 1950, on 11th January 1951 and the highest and lowest prices for 1936–1948 and for 1950.

The general financial picture would therefore seem to be as follows:—

American aircraft shares are back to their highest level. The investing public reads the impressive order figures in official reports and argues that the aircraft industry can't go wrong in the long run. The jobbers calculate the inherent value of the shares and recommend their purchase. The fear that they may be speculative is at last disappearing.

On the other hand the American government's system of placing orders leaves the firms sufficient margin to form reserves and even the Excess Profits Tax will not make any vast difference here. Judging by the experience of the last five years the USAF will need to continue enlarging and supplementing its material for a good time to come. Wise companies, however, in spite of their armament orders, will not forget their customers from the air transport world, even though these will not become really valuable customers until some time in the future.

	End of 1949	1950 Highest	1950 Lowest	End of 1950	11. 1. 1951	1936-1948 Highest	1936-1948 Lowest
Beech	7 3/4	13 1/4	7 3/4	12 5/8	13 3/8	20 5/8	1/2
Bell	12 1/2	28 1/4	12 5/8	26 5/8	28 3/8	35 1/2	6 5/8
Bendix	36 1/4	53 1/2	34 1/2	52 7/8	55 5/8	63	8 1/4
Boeing	23 1/8	41 7/8	22 7/8	41	42 1/2	49 3/4	11 3/4
Consolidated Vultee	10 3/4	19	10 1/4	17 3/4	18 1/2	35 1/4	7 7/8
Curtiss-Wright	7 1/2	12 1/8	7 3/8	11 3/4	11 3/4	13 1/4	2
Douglas	71	97	69 1/8	95 1/2	102 1/4	108 7/8	26 1/2
Fairchild [6]	5	9	4 1/2	8 5/8	8 7/8	8 3/8	3/8
Grumman	19 1/4	29 3/4	9 3/8	26 3/4	27	13 7/8	2
Lockheed	24 7/8	38 3/4	23 5/8	38	38 5/8	45 1/4	10 5/8
Martin	10 5/8	21 7/8	9 7/8	20 3/8	20 1/2	45 3/4	8
McDonnell [7]	17 3/4	19 5/8	8 1/2	21 1/8	21 1/8	10 7/8	1/2
North American	11 3/8	18 5/8	10 5/8	17 3/8	18	29 1/4	3
Northrop [6]	6 1/2	14 7/8	6 3/8	13 3/8	13 1/4	15 3/8	4 1/8
Republic	6 1/8	16 7/8	5 7/8	16 1/8	15 7/8	24 7/8	1/2
United Aircraft	26 7/8	37 5/8	25 1/8	35 3/8	36 1/8	53 3/8	10 3/4

[5] Meanwhile this programme has already been increased. For 1950-51 the figures are: USAF $6,603,440,000, Naval air arm, $2,542,922,000.

[6] Curb Exchange.

[7] Free market. Prices are taken from "Stock Guide," Dominick & Dominick, New York (Prices for 11th January, 1951, from "Wall Street Journal").

Book Reviews

Ailes naturelles et Vol humain. — By Emile Mollard. — Librairie des Sciences Aéronautiques, Paris, 1950.

This pamphlet, which revives the much-discussed subject of human flight, is written by a non-specialist. Nevertheless his remarks are extremely interesting. He rightly decides against an imitation of birds' wings, with their bone and muscle structure, as this would mean excessively complicated mechanisms. Instead he studies the flight of insects and the structure of their wings, and suggests a wing structure based on that of the dragon-fly. He recognises the inherent difficulties but seeks ways of avoiding them. Wisely he advises enthusiasts against throwing themselves into the production of a "prototype" without first forming a study group of technicians (for the calculations) and skilled workers (for the construction). As the author himself says, *Ailes naturelles et Vol humain* is only a preliminary study which needs the aid of specialists and test equipment to complete it.

The whole is a carefully detailed study animated by the author's enthusiasm for his subject. (French.) *Rh.*

Defence in the Cold War. — A report by a Study Group of the Royal Institute of International Affairs. — Published by the Institute, London and New York, 1950.

The Royal Institute of International Affairs is, under the terms of its Charter, precluded from expressing an opinion on current problems in international affairs. The opinions and conclusions presented by the Study group under Donald McLachlan therefore represent the private views of the individual members of the group. Nevertheless the attitude of official circles in Britain is doubtless not far from that expressed here. Although this book was printed in September 1950 it is still, unfortunately, exceedingly topical. Unfortunately, because the weaknesses of the Atlantic organization which it reveals objectively, but unsparingly, have not yet been entirely overcome.

In the opinion of the study group the West's serious inactivity is due, just as it was before World War II, to uncertainty as to the adversary's real intentions. In those days, however, it was the governments who lagged behind the common sense of the man in the street, whereas today public opinion has lagged behind events. The group outlines ways and means of dealing with this alarming situation. It recommends the creation of the necessary land, sea and air forces, but does not give this point its main attention. The main conclusion can be expressed as follows: alliances are worthless, or even dangerous, if they mean that each nation relies only on its allies. (English.) *He.*

Taming the North. — By Hudson Fysh. — Published by Angus & Robertson, Sydney and London. Revised and enlarged edition 1950.

In 1919 Hudson Fysh, a young ex-lieutenant of the Australian Flying Corps, and a friend made a ground survey of the first Australian air service between Longreach and Port Darwin. He helped create QANTAS, became its first pilot, carried the first passenger and is today its Chairman and Managing Director. As a pioneer of Australian aviation he is the ideal person to write the story of the first Australian pioneers who conquered the Australian North on horseback and bullock carts, against fearful odds of hunger and thirst. Hudson Fysh does not merely describe these treks, he lives them, and the crinkly-haired, painted, war-dancing aborigines—who daily menaced the lives of these first settlers—become alive under his pen. His Company today is helping to complete the economic organization of North Australia. Thus the cycle is now complete. (English.) *He.*

Stand und Entwicklungsfragen des Luftgüterverkehrs 1948. (Thesis presented at the University of Berne). — By Roger Zahnd. — Printed by Polygraphische Gesellschaft, Laupen-Berne, 1950.

It is only of very recent years that the urgent necessity for a scientific examination of air freight traffic has been recognised and such a study undertaken. The author chose as his theme the analysis of European and American air freight traffic during the first years after the war, and within the limited scope of a doctor's thesis, does it full justice. The careful evaluation of international literature increases the value of this brochure, which should find a place in every aviation library. (German.) *He.*

Guide Touristique Aérien — France. — Edited by the Société Française pour le Développement de l'Aéronautique, Paris, 1950.

This Guide contains all the information a private pilot could possibly need for flight over France. It opens with an introduction, an aeronautical vocabulary (French - English - German - Italian - Spanish) then gives a brief resumé of the rules for air traffic in France, general aeronautical information, a list of French airfields (with plans and various details, such as nature of runways, rules for use, markings, etc.) and of airfields in neighbouring countries and North Africa. Finally a few pages are reserved for personal notes by the owner of the Guide, followed by an alphabetical index.—It is obviously impossible to give greater detail here of all the different types of information contained in the *Guide Touristique Aérien*. The editors have worked in collaboration with the French Technical Services and have succeeded in grouping together in a useful and attractive volume practically everything a pilot, French or foreign, needs to know for an air journey in France. This Guide will undoubtedly render valuable service to sports and private aviation. *Rh.*

Die Luftwaffe ringt um Stalingrad. — By Hans-Detlef H. von Rohden. — Published by Limes-Verlag, Wiesbaden, 1950.

The ever-increasing importance of the aircraft in tactical support of the ground forces and in the supply system makes this description of an unsuccessful combined air/ground operation particularly interesting. Much more can be learned from the reasons for a failure than from the greatest epic of victory. As the last chief of the *Luftwaffe's* Military Science Section, the writer was able to draw on official records, so that his own experiences at the front are supplemented by hitherto unpublished documents and authentic figures. (German.) *He.*

Zu spät. — Aufstieg und Untergang der deutschen Luftwaffe. — By Werner Baumbach. Second edition. — Published by Richard Pflaum, Munich, 1949.

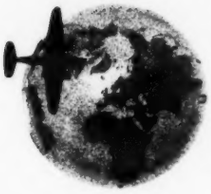
A *Luftwaffe* officer of the Hitler epoch, with the rank of a General, who was in almost daily contact with the Supreme Staffs, holder of the Knights Cross, intimate friend of Armament Minister Speer... In other words a typical example of the young generation of German officers who not only said "Heil" but literally waited for salvation until disaster overtook them. In this book he has worked himself free of his old masters—and it is never "too late" for the young to do this. When he says he "never wants to drop another bomb", he is obviously sincere. As, however, it is by no means certain that no more bombs will ever be dropped, this book is well worth reading. It contains not only an accurate account of the rise and fall of the *Luftwaffe*, but also interesting ideas on the air warfare of the future. *He.* (German.)

The Royal Air Force in the World War, Vol. IV, 1940–1945. — By Captain Norman Macmillan, M.C., A.F.C. — Published by George G. Harrap & Co. Ltd., London, 1950.

The fourth and last volume in Captain Macmillan's detailed history of RAF operations during World War II falls into two parts. The first deals with the work of the various RAF Commands (Fighter, Coastal, Bomber) in Europe from the beginning of the night battle over Britain in the autumn of 1940, through the battle of the Atlantic, the bombing of German cities and operations in support of the ground battles for France, Belgium, Holland and Germany up to the latter's final surrender in 1945. Part II describes the RAF's share in the Far East war against Japan.

Special operations in the European theatre dealt with in greater detail include the bombing of the Möhne dam, the airborne operations at Arnhem and Nijmegen and the German V1 and V2 attacks on London and Antwerp.

The narrative is based on careful examination of official documents and other sources and is enlivened by a number of personal anecdotes and eye-witness accounts. The author, Captain Norman Macmillan, needs no introduction to Interavia readers. *Js.* (English.)



What's in the Air?*

PAA STILL DOING BATTLE...

In October 1950 we reported a desperate last-minute attempt by Warren Lee Pierson, President of TWA, to get the merger between Pan American Airways and American Overseas Airlines postponed. He had appealed, unsuccessfully, to the Civil Aeronautics Board not to agree to the merger until approval of the transfer of services from AOA to PAA had been given by the aviation authorities of the European countries involved (*Interavia* Review of World Aviation, 1950, No. 10, p. 526). We remarked on that occasion that this distinct strengthening of an already powerful trans-Atlantic operator was no more welcome to the Europeans than to PAA's own American competitor TWA. It was another question how long the European governments could maintain their opposition.

This opposition has since been found to be surprisingly tough, in spite of the fact that PAA have been operating to Paris since 17th December 1950 and to Rome since 2nd January 1951. Originally the French and Italian authorities had tried to make the grant of landing rights to PAA subject to the condition that the transfer of AOA services should not lead to any increase in the total amount of space offered by the American companies. To achieve this Paris proposed a reduction in the number of flights by TWA (an arrangement which would probably not have been unwelcome to PAA). Nevertheless PAA was permitted to operate the New York—Paris service three times a week from 17th December 1950, using Boeing "Stratocruiser" sleeper aircraft for 47 passengers. At the same time, however, a special representative of the French Secretariat General for Civil Aviation went to Washington for further discussion with the Civil Aeronautics Board. A few days later it was reported that TWA were to retain all their existing services. It appeared that a new basis for cooperation had been found in a plan to limit the number of passengers to be carried by the two American companies. A joint French-American communiqué prescribed that the number of trans-Atlantic passengers carried by American companies should not exceed the number carried in 1950 by more than 20%. The Italian aviation authorities were less generous than the French and would agree to an increase of no more than 15% over the 1950 figure, saying that "Holy Year had produced exceptionally heavy trans-Atlantic travel to Italy."

Needless to say PAA are not at all happy about this restriction of the number of passengers they may carry, and even the French authorities do not appear to be exactly delighted with this provisional arrangement (three flights by PAA, thirteen by TWA, with a combined maximum of 700 passengers). A meeting of representatives of PAA, TWA and Air France is to be held in Paris at the end of January to try and work out a *modus vivendi* acceptable to all concerned.

Have PAA tried to stampede this conference? Have they harnessed the American Senate to their chariot for this purpose? Or was it just a happy chance that came to their aid, as so often in their history, when an old dispute between the American Colonial Airlines and the Canadian aviation authorities blew up again at just the right moment? It is difficult to say. The fact is, however, that at the end of December 1950 the American Senate approved a bill which will undoubtedly be on PAA's side in their European negotiations. Hitherto the American aviation authorities have had the power—based on a general authority granted by the US President—to conclude bilateral air agreements with the aviation authorities of other countries without sticking to strict diplomatic formalities. If the bill passed by the Senate should become law, air agreements will become subject to the same conditions as full-scale international treaties, namely approval by the President of the United States and two-thirds majority in the Senate. This complicated procedure would be used in all cases where it is a question of the grant of landing rights to foreign companies in America or the restriction of landing rights for American companies abroad.

It should not be too difficult to guess to whom this delicate hint is addressed.

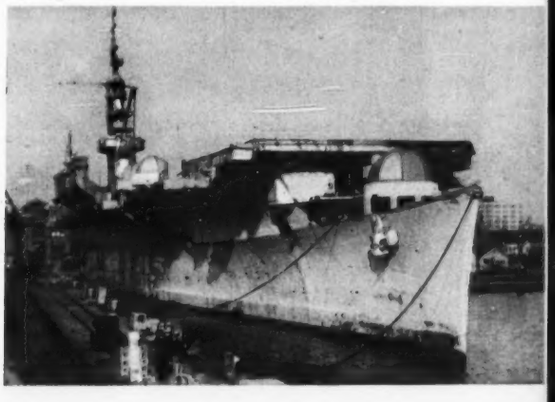
Military aircraft in short supply. Early in January 1951 a committee of experts from the North Atlantic Production and Supply Board visited all the leading aircraft works in the USA to investigate prospects for the supply of aircraft to the air forces of the various Atlantic Pact States. Inspecting a Lockheed F-94 allweather jet fighter (from left to right): Robert Kinkead (US), Herbert E. Hancocke of the British Ministry of Supply (in the cockpit), chairman of the committee, Colonel Noel Daum (France), Colonel Carlo Alippi (Italy), Gaston Fournier (France).

Guy du Merle, formerly head of the French school for commercial pilots, has been appointed *Director General of Civil Aviation in France*. He replaces Stéphane Thouvenot who has been nominated Deputy Director General of IATA in Montreal.

HOW TO BUY A SPARE PART

That the shortage of raw materials and the consequent creation of new official agencies to deal with it should cause trading difficulties is in no way surprising.

Events in Korea have proved once again that the naval air arm is indispensable. *Left :* Single-engined Grumman F9F "Panther" jet fighter on board the American carrier "Franklin D. Roosevelt." *Centre :* A British Hawker "Sea Hawk" landing on a carrier. *Right :* France is to receive the aircraft carrier "Langley" (18,000 tons) from the American Navy under the Military Aid Programme. The carrier in the Philadelphia Navy Yard after being "taken out of storage."



* Extracts from *Interavia Air Letter*, daily international news digest, in English and French. All rights reserved.

In the USA, it is true, a certain "rationalisation of the rationing agencies" was put in hand, at the time President Truman proclaimed the State of Emergency, with the creation of the *Defence Production Administration* which was given supervisory control over industry, transport, fuels, mining and power output. Needless to say, however, there is still no shortage of government agencies in spite of the creation of a central authority,—not to mention the raw materials and production authorities which have been set up in recent weeks in all the countries this side of the Iron Curtain (*e.g.* Australia, Italy, South Africa, Holland) and the *International Defence Production Board* of the Atlantic Powers, the organization of which has been entrusted to William R. Herod, President of the International General Electric Co.

First picture of the French SE 2410 "Grognard" twin-jet ground attack aircraft which has been under construction for some time by SNCA du Sud-Est.

At the end of January 1951 the British Hawker Siddeley Group granted (with the authorisation of the British Government) the American Wright Aeronautical Corporation a licence to produce the Armstrong Siddeley "Sapphire" jet engine (static thrust 1200 lbs.) *Sir Frank Spriggs*, Managing Director of the Hawker Siddeley Group and Chairman of Armstrong Siddeley Motors *(centre)* signing the agreement. *Left :* H. T. Chapman and *right :* W. T. Johnson, Managing Director and Director of Armstrong Siddeley respectively.

To non-American air transport companies the control of American production means not only that new American air equipment will be very much more difficult to obtain, but that the purchase of even the simplest spare parts for transport aircraft which have been in service for years will gradually become an almost insoluble problem. In future American aircraft companies will be able to supply spares to foreign customers only when orders have been cleared by the following authorities: State Department, Department of Commerce, Civil Aeronautics Administration and Civil Aeronautics Board. When all these clearances have been obtained, the order is passed to the National Production Authority, who coordinates production and delivery of spares in accordance with a general programme. In American aircraft industry circles the backlog of orders for spare parts at the end of the year was estimated at roughly $50,000,000.

*

It may be a slight consolation to air transport companies that the *air forces* of all countries not belonging to the North Atlantic Treaty Organization are experiencing equally great difficulties in obtaining aircraft—expecially modern jet aircraft. For example, delivery of Vickers-Supermarine "Attackers" to Pakistan has recently been delayed on instructions from the British Government, in spite of the fact that this country is a member of the Commonwealth and its Air Force is commanded by an Englishman, Air Vice-Marshal Atcherley. And when Atcherley made a flying visit to the USA in December to negotiate for the supply of American jet fighters, he had to return empty-handed. Egypt fared no better in her attempts, and Yugoslavia's military preparedness is suffering from a marked shortage of efficient aircraft and up-to-date radar equipment. Other European countries who have had firm contracts for several months will have to wait for varying periods for delivery.

Even the Atlantic Powers are by no means spared problems such as these, and the Anglo-Saxon countries (USA, Great Britain and Canada) are working on a plan for the systematic swapping of aircraft and engines which are scarce in one country but produced in another.—Early in January a group of experts visited all the aircraft factories in the USA to determine what deliveries the various air forces could count on.

RULE, AMERICA, RULE THE WAVES...

With the retirement in September 1950 of Louis A. Johnson, the anti-Navy Secretary of Defence, the way was opened for the expansion of the US Navy. The events in Korea have also helped to show that strategic air fleets alone are of little value and that for overseas operations an efficient naval air arm is still indispensable.

In the middle of December 1950 the American Congress decided to increase Naval appropriations by $1,659,000,000. Two thirds of this sum, which represents a part of the total supplementary credits of $18,000,000,000 requested for the Navy, are to be spent on the development of fleet and naval air bases in continental America, whilst the remaining third is destined for similar projects in the Atlantic and Pacific areas (Europe and Japan).

At the same time the Navy resumed its battle for a super-carrier, plans for which were cancelled by Johnson. According to a statement by a Navy Department spokesman, Admiral L. D. McCormick, at the end of December, the Navy proposes to lay down an aircraft carrier which is to be considerably larger than the carriers in service today (30,000 tons), but slightly smaller than the "United States" (65,000 tons) thrown out by Johnson.

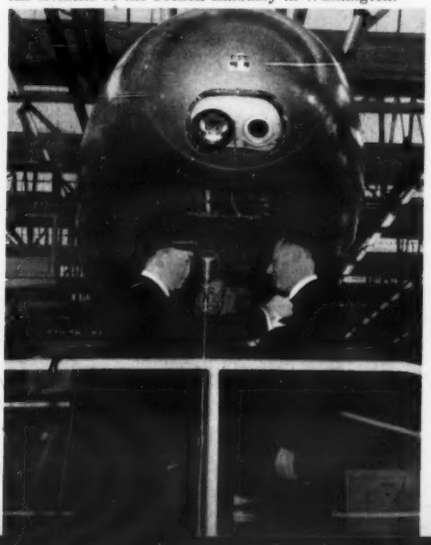
On 3rd January 1951, Carl Vinson, Chairman of the Armed Services Committee of the House of Representatives, asked for permission to build this carrier, and on 9th January the Armed Services Committee approved the project as part of a $2,000,000,000 programme, which provides for the construction of a total of 173 warships and the modernisation of 291 others.

A week later, on 17th January, the House of Representatives gave its consent. The new 57,000-ton carrier is to be finished by the middle of 1954 and to cost approximately $235,000,000. It will be capable of carrying atom bomb aircraft. The new programme also provides for the modernisation of six carriers of the Essex class and the conversion of two cruisers for rocket-firing.

Following the American example, other Atlantic Powers are also paying greater attention to their naval air services. Great Britain is converting the 10,000-ton cruiser "Cumberland" of the Kent class, launched in 1928, into a rocket carrier. Work is to be speeded up so that the first firing tests can be made in the spring of 1951. The aircraft carrier "Vanguard," the flagship of the Home Fleet, has already been modernised and can now carry the Navy's most up-to-date jet fighters. The carriers "Implacable" and "Victorious" (28,000 tons) are also to be converted in the same way.

The French Admiralty has decided to convert the cruisers "De Grasse," "Châteaurenault" and "Ghichen" into A/A cruisers, and Italy is shortly to receive an aircraft carrier from America under the Military Aid Programme (this will mean a revision of the peace treaty, which forbids Italy to possess aircraft carriers). Holland has just ordered six "Catalina" amphibians for her naval air arm, and the Australian 21st Carrier Air Group, trained in England, arrived in Australia in the aircraft carrier "Sydney" at the end of December. This new Group is to be stationed at Nowra naval air base along with the 20th Carrier Air Group which has been in service since May 1949. Although Nowra is not yet completed it is rapidly being developed into a modern, efficient operational base for the Australian naval air arm. The base already has its own technical training centre, an air-sea rescue unit (with Supermarine "Sea Otter" amphibians), armament and photographic training sections and repair shops.

In recognition of their services to French aviation the Presidents of two of America's leading aircraft concerns have been made Knights of the Legion of Honour. *Left : Robert E. Gross*, President of Lockheed Aircraft Corp., *right : Donald W. Douglas*, President of Douglas Aircraft Co., receiving the award from Brigadier General J. L. Murtin, Air Attaché to the French Embassy in Washington.



Ground Attack Missions and the Jet

by Major M. WÜTHRICH, Zürich-Dübendorf

Press reports on the employment of jet aircraft in the Korean war, particularly at the beginning of hostilities, denied that these aircraft had any value when used in ground support operations. Many successful ground attack pilots of World War II tended to endorse this view, pointing out that speeds of over 435 m.p.h. made it impossible to locate targets.

On the other hand, however, there is no doubt that the increase in speed resulting from the introduction of jet-propulsion brings with it valuable tactical advantages in ground support operations. The present article seeks to describe where the difficulties in the employment of present-day jet aircraft lie, how they may be overcome and what advantages can be expected in the future.

a) *Value of high speed during approach and return flight*

As a rule ground attack bases are not more than 125 to 185 miles (200-300 km) from the front. If, for example, the jet aircraft has a speed of approx. 560 m.p.h. (900 km/h) the approach flight will take about 12 to 20 minutes. It will frequently be carried out at low altitude to avoid radar detection.

The opposing fighters, which will not have very much greater speeds, must seek to reduce the element of surprise by maintaining constant patrols over the target area. This means the employment of large forces of fighters. Or they must have their bases in the immediate vicinity of the front, where they are highly vulnerable to attack by jet aircraft. The high speed of the jet attackers enables them to take the defenders by surprise.

b) *No special escort required*

The speed of jet ground attack aircraft is greater than that of traditional piston-engined fighters and therefore renders these useless as escorts from the beginning. Jet attack aircraft flying near the speed of sound have little to fear from jet fighters, whose speed is not much greater, particularly when the former have got rid of their bomb loads, as they are then just as manoeuvrable as the fighters. Moreover it is not very likely that they will encounter any fighters in view of their short time of approach.

This can best be illustrated by a small example *(fig. 1)*. It is assumed that the speed of the jet attack aircraft is approx. 560 m.p.h. (900 km/h = 250 m/sec) and that of the enemy fighters approx. 685 m.p.h. (1100 km/h = 305 m/sec). The first encounter between attacker and fighters occurs over the front line on a reciprocal course. The former's target is approx. 12 miles behind the front.

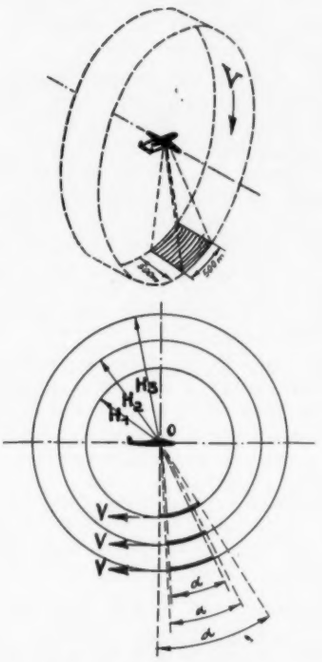
To get into a promising position for attack the fighter must make a 180° turn after meeting the ground attack aircraft. As in practice this turn will generally be made by a whole formation, it can be assumed that the centrifugal force will not be more than 2.5 times the flying weight (load factor approx. 2.7; banking angle 68 degrees). The fighter's radius of turn is therefore 2.37 miles (3.8 km) and the time required for a 180° turn is 39 seconds. During this time the bomber has advanced another 6 1/8 miles (9.8 km), so that the fighter, with its difference in speed (125 m.p.h. = 55 m/sec), will need 164 seconds, or nearly 32 miles (50 km), to get to within the firing range of 880 yards (800 m).

This example shows that under the given conditions the fighter would not be able to attack the intruder before it reached the target and that the latter would probably be back over friendly territory by the time the fighter could attack. As it would by this time have dropped its bomb load on the target it would no longer have very much to fear from the fighter.

c) *Influence of speed on target identification*

Here it is best to assume that the target to be identified lies within an area roughly 500 yds square (500 × 500 m). Experience has shown that the pilot can see this area without having to move the aircraft or his head.

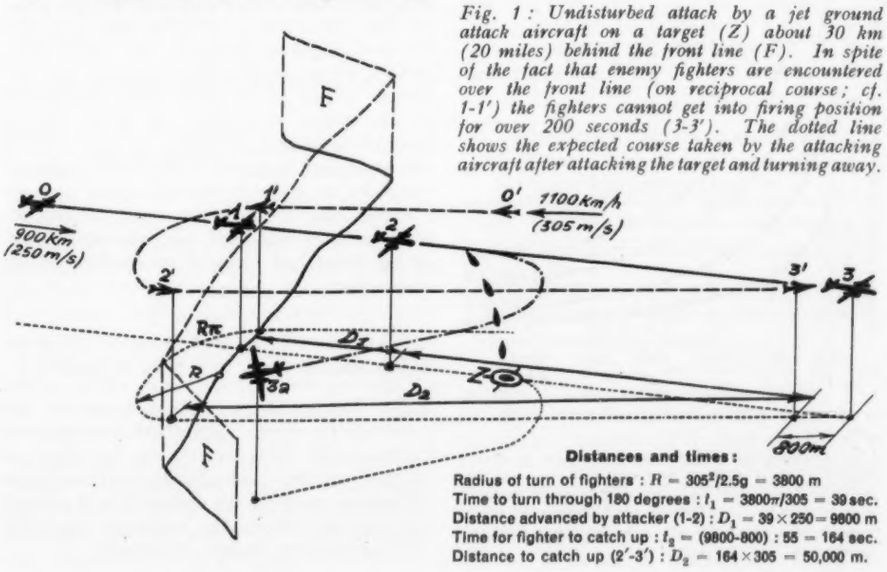
If the angular velocity at which the pilot's line of vision traverses the length of this area is calculated for various speeds and altitudes of flight, what can and what cannot be seen by the eye immediately becomes evident. As *fig. 2* shows, it is best to think



Angle of vision : $\alpha = 57.3 \times 500/H$ (degrees)
Time available : $t = 500 \times 3.6/V$ (sec)
Angular velocity : $w' = d/t$ (degrees/sec)

Fig. 2 : To determine the angular velocity of the line of vision at different heights of observation (H) and speeds of flight (V) the aircraft is imagined as stationary and a strip of country (500 × 500 m) as rotating round it.

Fig. 1 : Undisturbed attack by a jet ground attack aircraft on a target (Z) about 30 km (20 miles) behind the front line (F). In spite of the fact that enemy fighters are encountered over the front line (on reciprocal course; cf. 1-1') the fighters cannot get into firing position for over 200 seconds (3-3'). The dotted line shows the expected course taken by the attacking aircraft after attacking the target and turning away.



Distances and times:
Radius of turn of fighters : $R = 305^2/2.5g = 3800$ m
Time to turn through 180 degrees : $t_1 = 3800\pi/305 = 39$ sec.
Distance advanced by attacker (1-2) : $D_1 = 39 \times 250 = 9800$ m
Time for fighter to catch up : $t_2 = (9800-800) : 55 = 164$ sec.
Distance to catch up (2'-3') : $D_2 = 164 \times 305 = 50{,}000$ m.

of the aircraft as stationary and of the earth's surface as rotating about the aircraft at a distance equal to the latter's height. The above-mentioned 500 yd. square surface then becomes a ring section, the angle of whose two edges to their common centre depends on the height of flight. Since the speed is constant the eye always passes through this angle in the same time, and it can be seen that the angular velocity at which the area passes the eye increases with increasing height, so that identification of a target becomes more difficult.

Table 1 gives the angular velocities for observation heights of 3000, 2000, 1000 and 500 m (9750, 6500, 3750 and 1875 ft), and for speeds of flight of 1100, 800, 500 and 300 km/h (approx. 685, 500, 320 and 185 m.p.h.). The angle of vision can be calculated from the equation $\alpha = 57.3 \times 500/H$ (degrees); the time available for identifying the target is: $t = 500 \times 3.6/V$ (sec). The required angular velocity of the line of vision (in degrees/sec) is obtained by dividing the first value by the second.

The values in the Table are represented graphically in *fig. 3*, which also indicates the distance from which a number of uncamouflaged points can be recognized. A pilot can spot a man, for instance, from a height (or distance) of 500 m, a motor vehicle from 2000 m and a locomotive from 3000 m. These are average values as obtained in practice and will vary according to lighting and atmospheric conditions (haze etc.).

Experience has shown that pin-point targets can be spotted satisfactorily from a height of 500 m with the aircraft flying at a speed of 300 km/h. The angular velocity calculated for this case is therefore marked in fig. 3 as the limit value. If the angular velocity lies above this value observation will be difficult; if below, it is comfortable and therefore reliable.

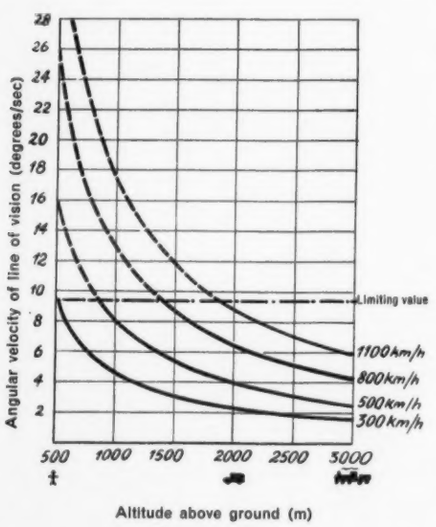


Fig. 3: Angular velocities of the line of vision plotted against altitude and speed. ——— curves in "good region", – – – – curves in "unsatisfactory region". The mean distances at which certain pin-point targets can be recognized are marked on the abscissa.

Height H	α	V = 1100 km/h t = 1.64 sec.	V = 800 km/h t = 2.25 sec.	V = 500 km/h t = 3.6 sec.	V = 300 km/h t = 6 sec.
m	degrees	°/sec	°/sec	°/sec	°/sec
3000	9.6	5.9	4.3	2.7	1.6
2000	14.3	8.9	6.4	4.0	2.4
1000	28.6	17.4	12.7	8.0	4.8
500	57.3	35.0	25.5	15.9	9.6

Table 1

The graph therefore shows that a jet pilot flying near the speed of sound (at 1100 km/h) meets the same conditions as regards the angular velocity of this line of vision at an altitude of 1900 m as he does at 500 m and a speed of only 300 km/h. The minimum height for reliable identification of a small target (truck, tank, etc.) is therefore about 2000 m above the ground for an aircraft flying at a speed of 1100 km/h. From this height the normal eye can just recognize such targets, though no details can be seen. At 500 m above the ground the angular velocity for a speed of 1100 km/h is 3½ times as great as for a speed of 300 km/h. Targets can be *recognized* from this height, but it is very doubtful whether they can be *spotted*.

Thus the first great disadvantage of a jet aircraft flying near the speed of sound comes clearly to light. The question is only whether, for this reason alone, the use of such aircraft must be regarded as unprofitable, or whether the disadvantage can be overcome.

In the Korean war slow-flying aircraft have been used to spot targets and report their exact positions to the « Shooting Star » units. Another method would be for the jet aircraft to reduce speed to about 500 km/h while looking for the target. Technically this is quite possible and would make observation easier. In the first case the spotting aircraft is open to attack by enemy fighters and requires special protection. In the second the jet bomber flying at 500 km/h can also be surprised by fighters—even piston-engined ones.

Both solutions are tactically possible and both have been tried out in the Korean war. To sum up, it can be said that *the very high speeds of flight make it very much more difficult for the jet ground attack pilot to find his target. At heights of over 2000 m however uncamouflaged worthwhile pin-point targets can still be identified without difficulty. If for meteorological or tactical reasons the aircraft must fly at a lower altitude, speed can be reduced while the target is being located, or slow-flying aircraft must take over the location of the target and transmit its position to the faster unit.*

d) *Influence of very high speeds of flight on the destructive power of normal weapons*

By destructive power here is meant the "destructive energy" per attack to be devoted to the target. This involves the investigation of the question of whether the various types of weapon used for the destruction of normal targets can deliver the necessary quantity of ammunition, rockets or bombs.

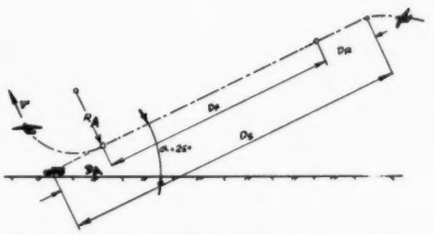


Fig. 4: Low-level attack on a pin-point target in diving flight. The sighting distance (D_S) must suffice for aiming, firing and pulling out.

Fig. 4 shows the course of such an attack in diagrammatic form and simultaneously fixes the most important values. The following symbols are used:

D_S (m): distance at which a pin-point target can be seen (truck);

D_R (m): distance required to aim aircraft;

D_F (m): "firing distance" available from aiming of aircraft to last possible moment for pulling out. (Applies only in part to rocket-firing and not at all to bombing.)

R_A (m): pulling out radius, e.g. for a maximum permissible acceleration of 4g.

D_A (m): pulling out distance, which is equal to the pulling out radius for a mean angle of attack (25°).

t_r (sec): time required for pulling out (value obtained in practice 2-3 sec).

t_F (sec): time available for firing.

n_F (rounds): total number of rounds possible for a given weapon.

The following values are assumed:—

Speeds of attack: 1100, 800, 500 and 300 km/h.

Guns: four 20-mm cannon, with a rate of fire of 800 rounds per minute per barrel.

Rockets: eight, with a release time of 4/10 sec, released two by two.

It is also assumed that the target in question can be destroyed by 10 direct hits from the 20-mm cannon and that to get this number of direct hits about 120 rounds have to be fired on an average. Finally that the same destructive effect can be obtained by one rocket direct hit and that on an average a salvo of 8 rockets has to be fired to produce one direct hit.

V km/h	V m/sec	D_S m	$R_A = D_A$ m	D_R (for 2 sec) m	D_F m	t_F sec	n_F rounds
1100	305	2000	3150	610	—1760	—	—
800	222	2000	1670	444	— 114	—	—
500	139	2000	655	278	+1067	7.7	410
300	83	2000	234	166	+1600	19.3	1030

Table 2

The *results* of this investigation are shown in *Table 2.*

Formulae used :

pulling out radius : (approx.) $R_A = \frac{V^2}{gn - g}$;

firing distance :

$D_F = D_S - (D_R + D_A)$.

However, it is not only the actual firing distance available which is important in our example, but also, and above all, *the distance required* for firing 120 rounds of 20 mm ammunition or 8 rockets (which are required to destroy the target in question), such as is calculated in *Table 3* for a firing time of 2.25 sec (cannon) or 0.4 sec (rockets) :

Speed of flight		Firing distance required for	
		cannon	rocket
km/h	m/sec	m	m
1100	305	685	120
800	222	500	90
500	139	315	55
300	83	185	35

Table 3

The values in Tables 2 and 3 are drawn in *fig. 5.* It will be seen that :

— in an attack from a distance of 2000 m from the target at speeds of over 780 km/h there is no time available for firing ;

— if the 8 rockets required to destroy the target are to be released from a distance of 2000 m the speed must be reduced to 760 km/h ;

— in the same conditions the speed must be reduced to as little as 680 km/h to enable 120 rounds to be fired from the cannon.

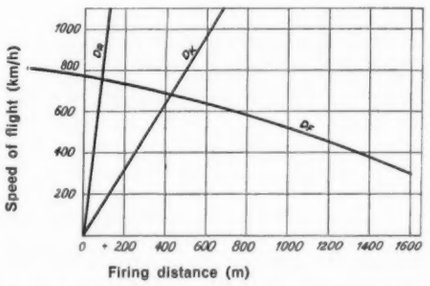


Fig. 5 : Graph showing the firing distance required for cannon (D_K) and rockets (D_R) plotted against speed of flight, and available firing distance (D_F) with given sighting distance (2000 m).

From this it may be concluded that the armament of high-speed jet aircraft must be so designed that the destructive energy required to destroy a target can be released within the shortest possible time (fraction of a second) after the end of the aiming process.

This requirement cannot be filled in cannon of conventional design. This is doubtless one of the main reasons why jet aircraft, originally built as fighters, with armament simply taken over from piston-engined fighters, inevitably failed when employed in support of the ground fighting, or at least showed up badly in their destructive effect in comparison with fighter-bombers of traditional design.

Jet aircraft are even obliged to reduce their speed considerably (to less than 760 km/h) to launch a rocket attack. This can only be done if they are fitted with efficient air brakes which reduce speed without producing vibrations in the aircraft —so that aiming is not disturbed. If, however, it is not desirable from the tactical point of view to reduce speed during the attack, the rockets must be released from a greater range. Since dispersion increases with the distance, this means that a larger salvo of rockets must be fired, e.g. four rockets being released every tenth of a second. The disproportionately high consumption of ammunition for the second procedure will probably lead to the development of guided missiles or even target-seeking projectiles for use by jet aircraft. The technical bases for the production of such projectiles already exist, so that it is unlikely that the tremendous advantage of high speeds will have to be sacrificed solely because of the question of firing distance.

e) *Anti-aircraft defence and increased speeds of flight*

Here it is sufficient to consider small-calibre anti-aircraft defences, which constitute the ground attack aircraft's principal enemy. The laying speed of a good 20 mm A/A gun is roughly 17°/sec. An aircraft flying at a speed of 1100 km/h and a height of 800 m over an A/A gun demands from the latter a maximum laying speed of 22°/sec (cf. *fig. 3*) and will fly through the practical firing range of about 1500 m in approx. 5 seconds. A gun firing at the rate of 800 rounds per minute or 13 rounds per second can fire only 65 rounds in this time.

The high speed of the jet aircraft also makes it much more difficult to organise an efficient warning system for A/A defence. All three factors mentioned here multiply the difficulties already experienced by A/A units in picking up and firing at ground attack aircraft. For these reasons too the air tactician will demand the highest possible speeds from ground attack aircraft and try to eliminate the consequent disadvantages by adapting armament and tactics to suit the high speed.

As regards the vulnerability of jet engines to A/A fire, it would appear from reports of experience in Korea that it is no greater than that of air-cooled piston engines. However, such great energy is stored up in the high-speed rotor that if one blade of the turbine is shot away the force created would be too powerful for the engine. In view of the relatively small dimensions of the rotor, however, such an incident must be regarded as an unlucky chance. For example the fuse of a 20-mm shell would be actuated as soon as it hit the engine casing. On the other hand an armour-piercing shell would cause considerable damage.

Strikes in the wings and leading edges of the tail surfaces are naturally very dangerous in a high-speed aircraft, since the high dynamic pressure completes the work of destruction.

f) *Speed and weather*

It cannot be denied that a low-lying cloud cover is dangerous for high speed flight, particularly in mountainous and hilly country. In settled weather when the height of cloud remains the same, the pilot of a high speed aircraft who is familiar with the country will have tactical advantages over the pilot with less local knowledge.

For some time to come both sides will probably have piston-engined aircraft which they can use with success in bad weather conditions. It would however be foolish to sacrifice the tactical advantage of high speeds solely on account of the difficulties encountered in bad weather.

Wartime experience has shown that, with few exceptions, major actions are not undertaken until good weather is assured, when the air arm can be certain of being able to play its full part. In such conditions it is important for both sides to have ground attack aircraft of the highest possible performance.

g) *Concentration of forces, take-off and landing runs, fuel consumption, operational readiness and maintenance.*

Air attacks on ground targets can be likened to the production line of a modern factory. If the speed of the line can be increased the output increases accordingly. Greater speeds of flight therefore mean an *increase in fighting power.*

The jet aircraft produced up to now require a *take-off and landing* runway 1500 to 2000 m in length. To keep airfields of such a size constantly in good condition in spite of bombing or during rapid advances is a difficult task for the ground organisation. Technically, however, it is quite possible to make even the fastest jet aircraft so that it needs no more than 400 m for

take-off or landing. The tactician of the future will not wish to be without this advantage.

Fuel consumption, as is known, is higher in jet than in piston engines, particularly so at low altitudes. Nevertheless the tactician will still not be willing to sacrifice his high speeds on this account, but will demand that the technician provide the jet aircraft with the endurance which he regards as essential. It is probable that this requirement has been met in the latest jet aircraft.

Finally it should be pointed out that jet aircraft can take off immediately after the engines have been started, without delay for warming up. This gives them a tactical advantage over piston-engined aircraft, whose engines have first to be warmed up, an advantage which is especially valuable for ground attack missions. Less time is required for maintenance of a jet than a piston engine.

*

Conclusion

The answers to the questions considered above have shown that the jet aircraft's initial lack of success on certain missions is readily understandable, since the development of aircraft, insofar as speed is concerned, has outstripped that of armament and since even the tacticians failed at first to recognize the full nature of the new conditions. Meanwhile no air force will now wish to deprive itself of the advantages of high speeds.

The jet aircraft was born of the exigencies of war and unquestionably represents an advance. Its value, even as a ground attack aircraft, is beyond doubt and a return to the piston engine is unthinkable. Moreover the jet ground attack aircraft has every prospect of proving the defence equipment now in service with the troops completely inadequate.

The Gyro Gun Sight

The problem of aircraft sighting in which both the target and the gun platform are moving in space with no relation to each other has always been one of the most difficult to solve. The principle of firing ahead of moving targets in order that the bullet will arrive at a point at the same moment as the target is essentially easy enough to understand, but its application is another matter. In the First World War the speed of the parent aircraft was catered for in the case of movable guns by a wind vane, which offset the bead sight on the gun barrel in relation to the slipstream into which it was projected, but no method of allowing for relative movement was evolved for the fixed gun sight other than the pilot's judgment in relation to a fixed ring and bead mounted on the aeroplane. By the time the Second World War broke out the speed of aeroplanes had trebled and simple judgment of range and deflexion by the pilot was virtually impossible. To overcome the range difficulty the reflector sight was developed, in which an illuminated sighting graticule was projected on to a screen in front of the pilot. This graticule was adjusted by the pilot to a setting corresponding with the span of his target and then he maintained this target within the graticule and adjusted the latter to be always the same size as the image of the target by a control on his throttle lever. This change of the size of the graticule automatically made corrections for the range of the target in relation to the gravity drop of the bullets.

The simple reflector sight was inadequate because the pilot still had to make his own adjustments for deflexion and turning [1]; so toward the end of the war the armament specialists of the Air Ministry and the Ministry of Aircraft Production in Great Britain developed the gyro gun sight, the G.G.S. [2] Several versions of the G.G.S. are today in existence, some of which are still classified " Top Secret ". The sight described in the following paragraphs has been delivered to several European nations who have bought British jet-propelled fighters. It is designated " Mark IVB " and produced by a large firm of radio equipment manufacturers, Ferranti, Ltd., Edinburgh. (Figs. 1 and 2.)

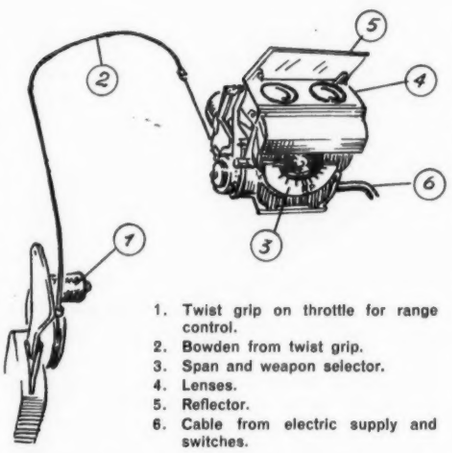
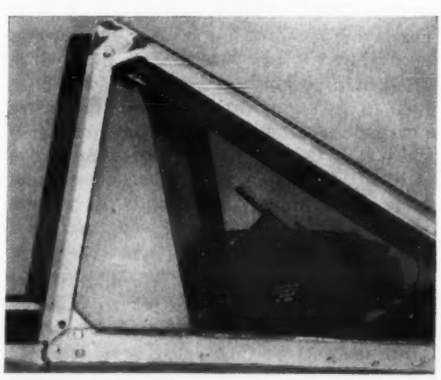

1. Twist grip on throttle for range control.
2. Bowden from twist grip.
3. Span and weapon selector.
4. Lenses.
5. Reflector.
6. Cable from electric supply and switches.

Fig. 1 : The British gyro gun sight " G.G.S. Mark IV B " and its twist grip range control.

Fig. 2 : The British gyro gun sight (Ferranti) in a fighter cockpit.



Briefly, this sight is a computing mechanism which takes into account the velocity and trajectory of the missile (i.e., .5 in., 20 mm, or R.P.), the range of the target, and allows for the turning of the attacking aeroplane. The pilot has a transparent reflector screen upon which are projected two graticules, one being a fixed ring with a cross in the centre, and the other a circular pattern of six diamonds with a centre bead. When the pilot is flying straight, the two graticules will be super-imposed, but when he is turning to the right the moving graticule of diamonds lags behind the turn and appears to the left of the fixed ring-and-cross pattern. That is to say, the pilot will sight through the diamond pattern while his guns will point in the line of the ring and cross. The

[1] Firing in a turn (frequently also in diving or climbing flight) became necessary not only in dog fights between fighters but also because the very effective defensive armament of bomber formations made it more and more difficult for fighters to approach from the rear.

[2] Similar gyro gun sights were developed in America and were used during the war (" Mustang-sight ") ; at the end of the war a gyro sight was being tried out in Germany, but it never came into use in quantity.

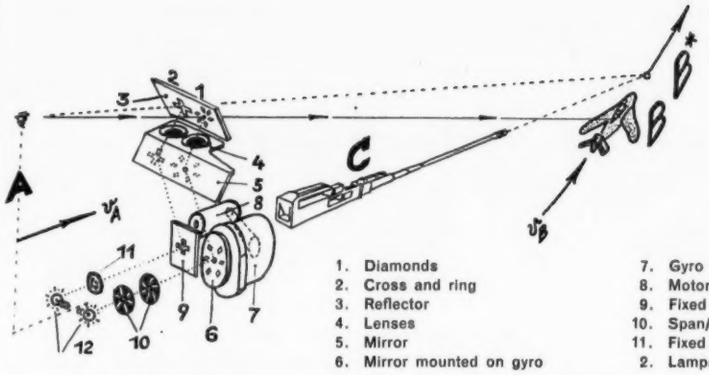


Fig. 3 : Simplified diagram of the optical system and centrifugal gyro in the gyro gun sight. Pilot A *follows enemy aircraft* B *in a lefthand turn (graticules* 1 *and* 2 *therefore do not coincide). He holds the enemy in graticule* 1*, whilst cannon* C *fires in the direction indicated by its barrel which lies in the same plane as the dotted sighting line and the speed sector* VA*. When the enemy's span is correctly set the deflexion of the two graticules gives the necessary "lead"* B–B*.

angular difference between these two images represents the deflexion necessary to allow for the aircraft's turn.

So much for the deflexion due to the turn. The range of the target naturally comes into the question also and this is controlled in two ways. Before combat a knob on the instrument is set to give the correct internal adjustments for the span of the enemy, e.g., 30 ft. Thereafter, so long as the pilot adjusts the size of the diamond graticule to correspond with the span of the target as he sees it, by means of the twist grip on his throttle lever, the instrument will be adjusted internally to take into account the range.

To understand this question of range and deflexion, the following elementary optical principle must be understood, that the angle subtended by the eye to an object records its size and that this angle is inversely proportional to the range of the object. It is this fact, using the pilot's eye and the adjustable graticule on the reflector screen as a means of measuring the angle, which makes it possible for the instrument to find the range of the target. When adjusting the graticule to fit the target by his twist grip, the pilot is operating the range finding mechanism within the sight.

The deflexion caused by turning is computed within the instrument by an electro-magnetically controlled gyro which responds to the turning of the aeroplane and to the constraint put upon this gyro by the range-finding mechanism.

Before going any further, it is as well to point out that, in addition to being pre-set for the size of the target, the instrument has to be pre-set for the trajectory of the missile [3] —after this the whole work is done by the sight and the pilot makes his adjustments with the range-control twist grip. The sight itself consists of the following items :—

[3] To ensure accurate sighting there is a growing tendency to limit the armament of a given jet fighter to one standard type (cannon of the same calibre).

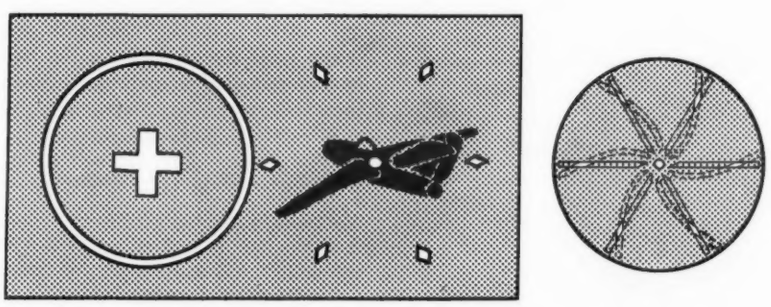


Fig. 4 : The left-hand half of the picture shows the displacement of the diamond graticule from the central position towards the right, i.e. during a left-hand turn. The enemy is held in the circle of diamonds, the diameter of which can be varied by means of the two graticules shown on the right. The front graticule is set at the beginning of the battle to correspond to the span of the enemy; the rear graticule can be adjusted by means of the range-control twist grip. Thus the diamond circle need not necessarily appear in the indicated position, but may also be to one side. The cross (in the centre) shows the firing direction of the cannon. It thus points to the spot which the enemy will reach at the same time as the bullets.

1) The sighting head which contains the gyro and its motor.

2) The throttle twist grip control.

3) The R.P. selector switch.

4) Various associated electrical equipment which makes the necessary cohesion between the instrument and its controls.

Fig. 3 shows how the items are controlled. The fixed graticule, which always represents the line in which the guns are pointed, is projected on to the screen by a light and a masking pattern from inside the gyro sight box, and it is always in the same place on the sighting reflector.

The range-finding and deflexion indicator graticule is the one the pilot uses to find his line of sight. As has been said already, in straight flight the two are superimposed. The image cast on the reflector screen is made up from two graticules, one called the span graticule consisting of six radial lines from a central point and the range graticule consisting of six *curved* radial lines from a central point. These two graticules are rotated electrically by the pilot's range-control twist grip and as they move in relation to each other they vary the diameter of the diamond pattern image formed by their points of intersection (Fig. 4). These two graticules cast their combined image on to a mirror mounted on the gyro, which throws them to left or right whenever the aircraft turns in one direction or the other. The gyro is, of course, responsive to the rate of turn of the aircraft. When the range control twist grip is turned, as well as altering the relative position of the two graticules, it applies an electro-magnetic restraint to the gyro so that the deflexion of the image is restricted according to the distance of the target. The final deflexion of the image therefore is proportional to the time of flight of the bullets, i.e. to the distance measured by the range finder—the farther away the target and the greater the rate of turn the greater the deflexion.

The two graticules, fixed and movable, on the reflector screen of the sight serve also to help the pilot when making allowance for the speed of the target, which cannot, of course, be computed by the sight.

The gyro gun sight is basically designed for stern attacks, where both aircraft will be moving on similar flight paths. It is also suitable however for low level attacks on vehicles travelling on road or rail. A particular advantage of the sight is that it does away with the use of tracer ammunition, since it is no longer necessary to correct the "lead" provided the sight is properly operated. The fighter attack therefore has a greater element of surprise.

Trajectories of interception

The problem of the interception of an aircraft A by a pursuer C is very complex since its solution depends on the flight characteristics of the two aircraft and their method of control and guidance. For each case there will be a most satisfactory trajectory for pursuer C corresponding to a clearly defined curve. This article proposes to discuss briefly these curves, the most important of which are : the curve of pursuit or the dog's curve, the path of encounter or future position, the curve of alignment or scout's curve, the accelerated curve of alignment, the trajectory to the probable future position and finally the curve of pursuit when aircraft A seeks to avoid interception.

1. *Curve of pursuit or dog's curve*

This is the curve followed by a moving pursuer C (dog or fighter) travelling towards another moving object A (his master or the aircraft to be intercepted). In studying this problem it is assumed that the speeds of the dog V_C and of his master V_A are constant and that the master is moving along a straight line (fig. 1).

In these conditions the dog can catch up with his master only if his speed V_C is greater than V_A. In any case the time required for interception is greater than that which would elapse if the dog followed the « path of encounter » of the two moving objects. Moreover if the dog and his master are moving towards each other (which will be the most frequent case in interception), the dog will be obliged to make a very close turn at the last moment, since he always joins his master from the rear irrespective of the initial direction of the two moving bodies.

All these properties of the curve of pursuit tell against its employment as an interception trajectory. The path of encounter, which is shorter, enables the target to be reached even if the « dog » moves more slowly than the « master », and this in a shorter time and without a turn.

If such are the disadvantages of the curve of pursuit, it may well be asked why this trajectory figures among those considered for interception, and why dogs with their keen instincts should employ it for joining their masters.

If we watch what dogs do we see that they only follow « their » curve when their master is walking slowly, and the dog does not know whether he is going to stop or make a half-turn, or in other words when the « future position » is not known. The dog's curve is then the best one to follow and instinct does not deceive the dog in causing him to follow this trajectory. On the other hand if the master is moving at great speed, on a bicycle or in a car, for example, the dog clearly follows the trajectory of encounter to the future position, which his instinct tells him is correct, just as if he knew how to construct a triangle of velocities.

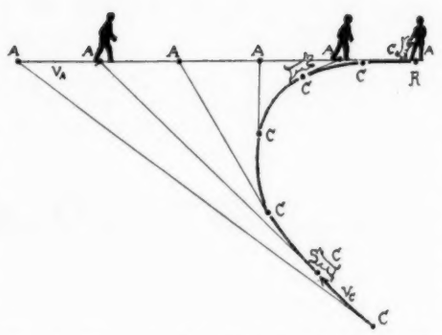


Fig. 1 : The curve of pursuit or " dog's curve " is followed by a dog C *running at a constant speed* V_C *towards his master* A *who is walking in a straight line also at a constant speed* V_A.

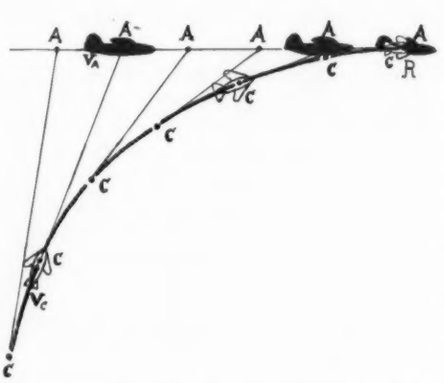


Fig. 2 : As a trajectory of interception the dog's curve has the advantage of being easy to follow for a pursuer C *: the pilot need merely head constantly towards the aircraft* A *to be intercepted.*

For the fighter pilot wishing to intercept an aircraft the problem is the same as for the dog. If he knows that the aircraft is moving too fast to change direction or that it is not piloted or guided from the ground he should not use the dog's curve. But if the aircraft can make turns, half-turns, climb, descend, accelerate or slow down during the pursuit, its future position will be unknown and the fighter should use the curve of pursuit This is quite easy particularly for piloted machines, for all the pilot has to do is to set his course constantly for the aircraft he is pursuing (fig. 2). On the other hand the use of the dog's curve for remote-controlled machines would be so complicated that it is not of practical interest.

Seen by an observer in aircraft A flying on a straight line at constant speed, the curve of pursuit described by the fighter becomes the swimmer's curve, that is the path covered by a swimmer who aims constantly at the same point on the river bank but is carried downstream by the current (fig. 3).

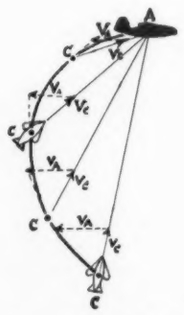


Fig. 3 : Seen from aircraft A *the pursuer* C *(who is following the dog's curve) seems to be following the " swimmer's curve ", that is to say the curve which would be described by a swimmer* C *heading at constant speed* V_C *towards a fixed point* A *on the bank but carried away by the current at a constant speed* V_A.

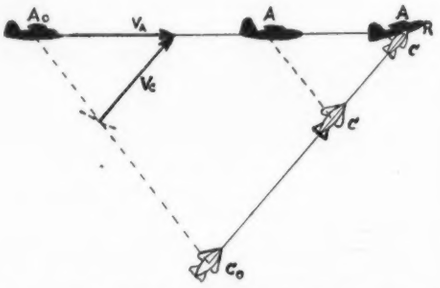


Fig. 4 : The " path of encounter " or " trajectory to future position " is the straight line which pursuer C *must follow to meet aircraft* A *at point* R. *By forming the triangle of velocities with* V_A *on* AA *and* V_C *starting from the initial line* AC, *the straight line of encounter* CCR *is parallel to* V_C.

2. *Path of encounter or of future position*

If the trajectory of aircraft A is accurately known to the pursuer C, the latter must, in order to reach A as rapidly as possible, move in a straight line towards point R on A's trajectory at which A will have arrived after a time equal to that taken by C to get to the same point R (fig. 4). This problem does not present any difficulty, but as A's trajectory can only be regarded as fixed and known in cases of pursuit over a very short distance or when A is a projectile or a rocket-bomb of the V2 type, it has been necessary to provide a device to furnish point R automatically and to send off fighter C automatically once the radar has fixed three positions of aircraft A at intervals of one second (fig. 5).

A gyroscopic mechanism attached to the fighter's radar has also been developed to guide him automatically, causing him to return to the trajectory of encounter even if he deviates from it momentarily.

Thus it is seen that of all the imaginable trajectories of interception, the trajectory of encounter is the most favorable from the kinematic point of view, since all the fighter has to do to intercept aircraft A at point R or « future position » is to fly on a straight line at his maximum speed. He has no need to make turns which his manœuvrability or his speed might render impossible. The sole disadvantage of this trajectory is that it can only be used when the aircraft to be intercepted cannot leave the trajectory determined by the three points observed by radar (these three points being sufficient to fix the position of the curve) the speed and acceleration and the nature of aircraft A.

3. *Curve of alignment, or scout's curve*

Let us suppose that a scout C is moving at a constant speed towards a straight road along which a car A is travelling which he wishes to observe without himself being seen by its occupants and that to do this he always keeps a tree O between him and the car. The curve he describes is thus the trajectory of an object C moving with a constant velocity (always keeping in line with a fixed point O) and of another moving object A travelling at constant velocity in a straight line (fig. 6). This trajectory is also called " curve with three points in line ".

The value of this curve as an interception trajectory rests on the facility with which it lends itself to remote control. Once aircraft A has been detected, by the eye or by radar, a robot calculator regulates an automatic control mechanism on board fighter C and controls the movement of C in such a way that if aircraft A continues to fly without changing direction or speed, the fighter will describe exactly the scout's curve. This can be checked at the point of departure by watching the aircraft and the fighter whose reflections should always coincide (fig. 7). As soon as they move apart the remote control must be corrected in the requisite direction to cause the two reflections to coincide again.

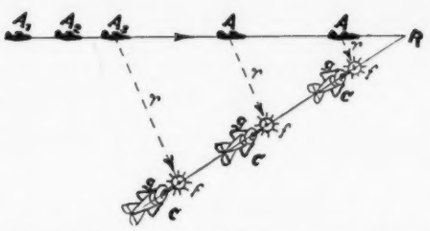


Fig. 5 : The trajectory of encounter can be followed automatically by pursuer C. *A cell controlled by a gyroscope* g *receives reflected ray* r *from the radar and acts on the controls each time ray* r *falls on the cell at a different angle. The angle between the direction of the reflected ray and the heading of the aircraft—or the trajectory of encounter* CCR*—should be constant.*

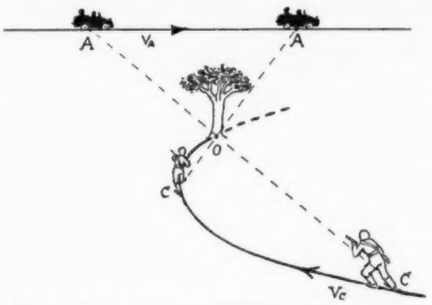


Fig. 6 : The " curve of alignment " or " scout's curve " or " curve of three points in line " is the route followed by a scout C *advancing at a constant speed* V_C *towards a car* A *travelling along a straight line at a constant speed* V_A, *so that he is always hidden by tree* O.

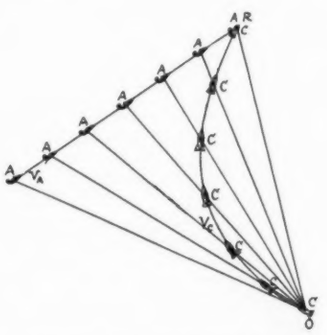


Fig. 7 : The scout's curve is used as a trajectory of interception because it is easy to apply to remote-control. It is sufficient to ensure at point of departure O *that the image of pursuer* C *always coincides with that of aircraft* A *to be intercepted.*

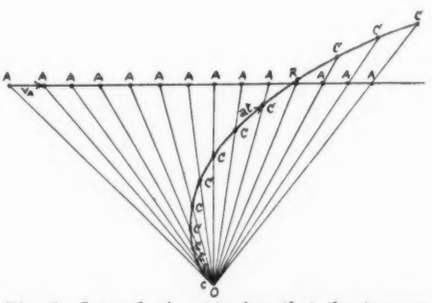


Fig. 8 : Instead of supposing that the pursuer has a constant speed V_C, *it is nearer reality to regard it as travelling at a speed* at *which is constantly increasing (*a = *constant acceleration,* t = *time). The curve described by* C *always meets the trajectory of* A.

By following the scout's curve the pursuer is certain of reaching his target if his speed is greater than that of the aircraft to be intercepted, and even in many cases if his speed is lower. The time lost is less than for the curve of pursuit, which increases the value of the scout's curve for interception purposes.

It should be pointed out that the mathematical problems raised by the scout's curve are most interesting because of the rarity of the form of the curve, its curious properties and finally the difficulty of integrating its differential equations.

4. *Accelerated curve of alignment*

The scout's curve or curve of alignment which has just been discussed presupposes that the fighter's speed is constant. However, this condition is difficult to fulfil in practice because the fighter must start off from the ground at zero speed, even if it is catapulted, then climb at a steeper and steeper angle until it zooms or even flies upside down, and make tight turns to maintain the alignment. It is very difficult to do all this at constant speed. Moreover, interception by means of a guided missile necessitates the use of a pursuing machine whose thrust greatly exceeds its weight and the aerodynamic resistance during the necessarily short time of pursuit. It would therefore be nearer to practical conditions to assume that the pursuing machine leaves the ground at zero speed and that its speed accelerates at a constant rate (fig. 8).

The mathematical calculations connected with this case are much more complicated than those of the scout's curve. However, through study of the properties of this equation and its graphic integration it has been possible to deduce the form of the curve, the duration of pursuit and even to calculate an apparatus for automatic control during the pursuit. The control post O on the ground

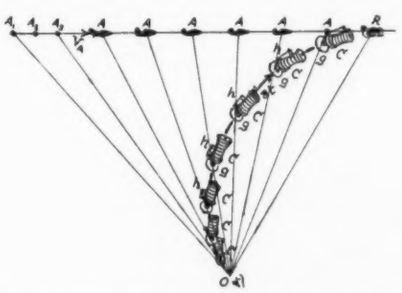


Fig. 9 : The trajectory of aircraft A *having been determined by three position measurements* (A_1, A_2, A_3), *an automatic device sends off pursuer* C. *The latter has a mechanism (camshaft actuated by a clockwork mechanism* h *controllable from observation post* O *on the ground) which causes it to follow the heading deduced from the equation of the accelerated curve of alignment. A gyroscope* g *provides a fixed system of reference.*

need only correct the trajectory of the pursuing missile whenever the alignment is lost (fig. 9).

Theoretically pursuer and pursued will always meet whatever the speed of the aircraft to be intercepted and the acceleration of the pursuer, but in practice there will be cases where the duration of pursuit will be excessive and the pursuer will not have sufficient range to reach his target.

5. *Trajectory to probable position*

It may happen that we know the type of the aircraft to be intercepted and its flight characteristics (maximum and minimum speeds, minimum radius of turn, maximum rate of climb, etc.) but that we have no information on its probable trajectory ; all movements, e.g. continuing in a straight line, turning to the left, turning to the right, climbing or descending, being equally probable.

In this case there will be for each moment a geometric figure of positions that are equally probable, forming a narrow crescent for the first second, a wider one for the second and so on. The geometric figure will form a closed space which will get bigger and bigger and will be limited by an extension of the circle corresponding to the tightest turn and by the " cardioid " of this circle (fig. 10).

The future probable position at any given moment is the centre of gravity of the geometric space figure of probable positions. It is therefore possible to find a mathematical law of the movement of this probable future position and the formula giving the direction which the pursuer must follow to reach his target with the greatest likelihood of success. The formula is very complicated, but it is found that for a limited period the location of the probable future position coincides more or less with the future position without deviation on the part of the aircraft to be intercepted. On the other hand, for a longer period, the probable future position coincides with the present position of this aircraft *A*.

Consequently if the aircraft to be intercepted is very close or if it flies at a high speed or even if its minimum radius of turn is very great, the trajectory of future position which has already been described can be used. On the other hand if the aircraft to be intercepted is very far distant, if its speed is low or if it can make very tight turns, the curve of pursuit should be used, course always being set towards aircraft *A*.

6. *Curve of pursuit when the aircraft seeks to avoid interception*

If aircraft *A* has a speed higher than that of pursuer *C*, it will have to fly straight in front of the pursuer at its maximum speed to escape interception. But if this direction is closed to it owing to some circumstance

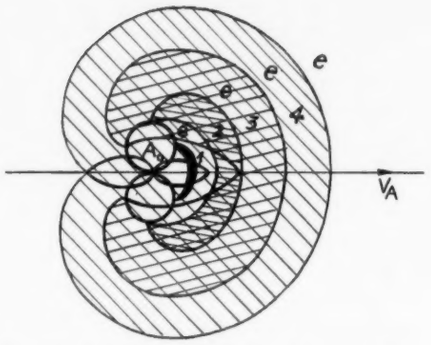


Fig. 10 : If the speed and the minimum radius of turn of aircraft A *are known, but not its destination, it is possible to determine, for any given moment, the zone of points which* A *can reach with the same degree of probability. The zones defined are marked successively 1, 2, 3 and 4 and are delimited on the one hand by the extensions of the circles of minimum radius of turn and on the other by the cardioids of these circles. It is found that at the beginning the probable future position moves with* A *and that finally it coincides with the initial position of* A.

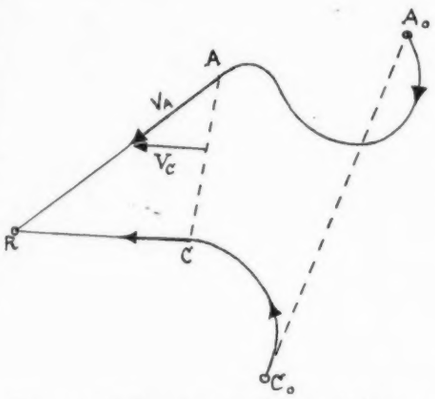


Fig. 11 : An aircraft at A *seeks to avoid interception by pursuer (at* C_O*). A's speed is superior to that of* C, *but* A *cannot get away by making a half-turn and has to take direction* AR. A *will be intercepted at* R *by the pursuer who has followed trajectory of encounter* CR.

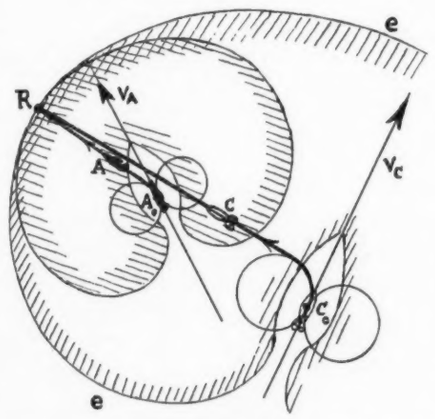


Fig. 12 : Let C_O *be the initial position of a pursuer charged with intercepting an aircraft which is at* A_O. *By tracing the zones accessible to each of the aircraft (or by using transparent sheets showing these zones), point* R *will be found where zone* A *touches zone* C. *It is by travelling towards* R *that* A *will have the greatest chance of escaping.*

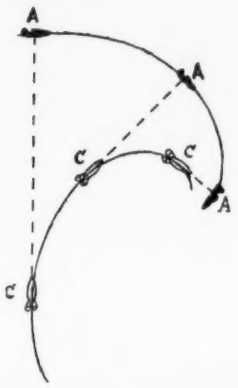


Fig. 13 : If aircraft A *wishes to escape interception by pursuer* C, *whose speed and minimum radius of turn are greater, it will always have to travel at right angles to the direction of flight of* C *to oblige the latter to make its turns tighter and tighter. The two aircraft describe a logarithmic spiral about the same point.*

or other, it will try to fly in a straight line at its top speed, and the pursuer will have to pursue it by that trajectory of future position which permits interception even in certain cases in which the pursuer has a speed lower than the aircraft to be intercepted (fig. 11).

If the speed of aircraft *A* is lower than that of pursuer *C*, it is probable that *C*'s minimum radius of turn will be greater than that of *A*, who can take advantage of this circumstance to escape interception by making tight turns. To solve this problem the geometric curves of the possible positions of the pursuer and the aircraft respectively from second to second are drawn on two transparent sheets. By superimposing the two sheets in such a manner that the initial positions of the pursuer and the aircraft correspond to those at the beginning of pursuit, the spaces which can be reached by the pursuer and the pursued in the same time can be determined. The aircraft should avoid these spaces, the pursuer on the other hand will try to force it to enter them (fig. 12).

By manœuvring correctly the aircraft can fly at right angles to the direction of flight of the pursuer, so that the latter will have to make his turns closer and closer, which leads to trajectories in the form of a logarithmic spiral (fig. 13).

In the preceding it has been supposed that all that was required was to bring pursuer *C* into contact with aircraft *A*. Needless to say the arrangement and power of the armament of pursuer and aircraft will have a great influence on the final result of the interception."

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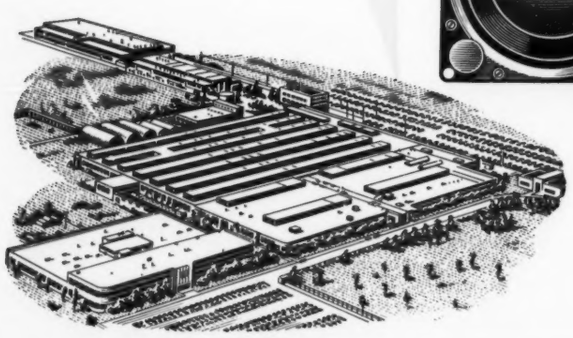

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